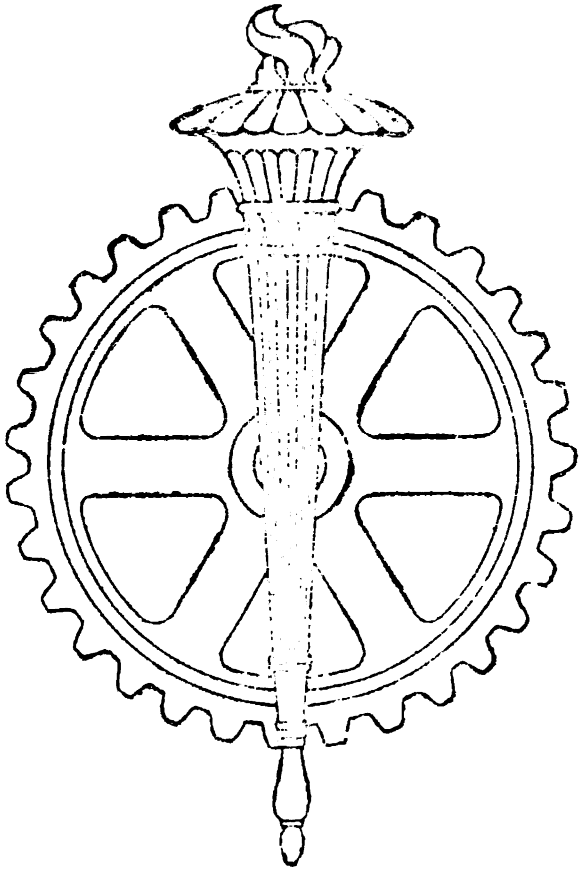

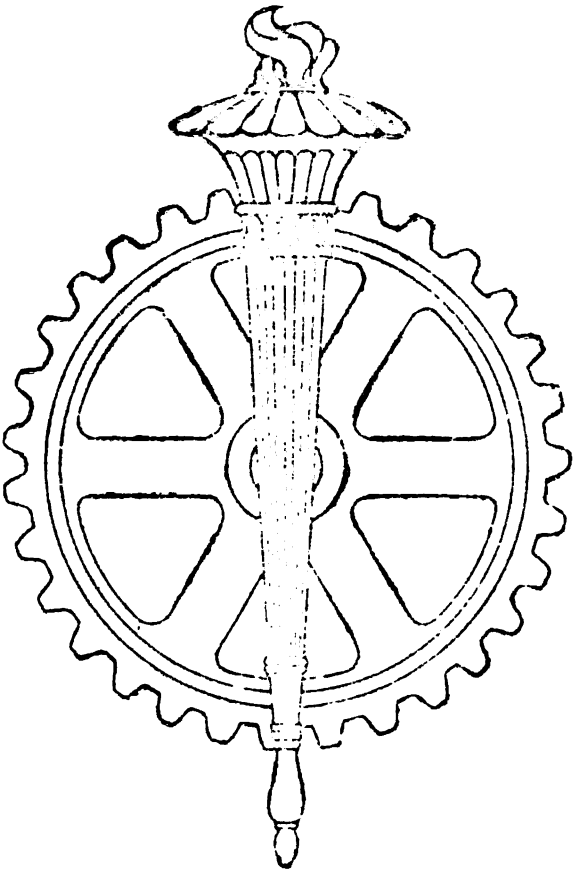

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TIME STUDIES AS A BASIS FOR RATE SETTING

As Developed in the Taylor System of Management

Time study for rate setting is the means to attain the fundamental objects in manufacturing of high wages and low labor cost.

FREDERICK WINSLOW TAYLOR

TIME STUDIES
AS A BASIS FOR RATE SETTING

BY

DWIGHT V. MERRICK
Member Taylor Society
Member The American Society of Mechanical Engineers

WITH A FOREWORD BY
CARL G. BARTH

NEW YORK
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1920

TO MY MOTHER

FOREWORD

NEW ideas always slowly find their way into popular favor. Unfortunately, some ideas while thus slow in getting under way, once they have taken root, spread further and faster than they can be properly assimilated by their votaries.

A striking example of this is the idea of "unit-time-studying" the various classes of human labor performed in the industries, in the manner first suggested and practiced by the late Dr. Frederick W. Taylor, now generally recognized as the Father of Scientific Management, of which form of management unit-time study forms such an important element that managers and other executives, quite generally, have lost sight of other elements that are even more important, for, without these as a foundation, proper time studies to be used as the basis of equitable task and rate setting are impossible.

While Doctor Taylor invented and used unit-time studies in a limited way some fourteen years earlier, it was not until June of 1895 that he gave the idea to the world in a paper entitled "A Piece Rate System," which he presented at the Detroit meeting of the American Society of Mechanical Engineers. Here he said:

> "Practically the greatest need felt in an establishment wishing to start a rate-fixing department, is the lack of data as to the proper rate of speed at which work should be done. There are hundreds of operations which are common to most large establishments, yet each concern studies the speed problem for itself, and days of labor are wasted in what should be settled once for all, and recorded in a form which is available to all manufacturers.
>
> "What is needed is a hand-book on the speed with which work can be done, similar to the ordinary engineering hand-books. And the writer ventures to predict that such a book will before long be forthcoming. Such a book should describe the best methods of making, recording, tabulating, and indexing time observations, since much time and effort are wasted by the adoption of inferior methods."

However, greatly to his disappointment, Doctor Taylor found at that meeting that his audience was so little prepared for his ideas and methods, that the discussions of his paper, though many and varied, centered entirely on his method of "differ-

ential piece rates" of paying for a task, instead of on his manner of determining the time allowance for the task, by means of unit-time studies.

It was not until he again presented his ideas as a part of a more general scheme of management, in his second paper before the same society—"Shop Management," read in December, 1903—that a limited number of shop managers and manufacturers began to realize what he was aiming at, in addition to the exceedingly few who, in the meanwhile, had fallen under his personal influence.

The importance that Doctor Taylor placed on time study is further emphasized by his statement that his object in writing his book, "Shop Management," was to call attention to this mechanism of management, and make sure that it should receive the consideration that it deserves. In fact, on fifty-two pages of that book there are references to time study, and on page 58 is this paragraph:

> "The writer most sincerely trusts that his leading object in writing this book will not be overlooked, and that scientific time study will receive the attention which it merits."

Since that time, the idea has spread much more rapidly than has an adequate realization of the difficulties that are connected with the making of time studies, and also of those that confront the person himself who undertakes to *put time studies over* in a shop; so that a great deal that is attempted along these lines miscarries in whole or in part. First of all, the mistake is only too often made of *sailing into* time studies before the shop equipment and methods have been properly standardized; and second, the mistake is made of supposing that a man of merely clerical experience provided with a stop-watch, can either on his own initiative make usable time studies, or may readily and quickly be taught how. However, this is far from the case, for time studies cannot be separated from motion studies, and motion studies cannot be made by a person who does not fully appreciate the purpose of the motions made by the operator he observes. Where a machine is involved he must also understand that machine, and the difference between its correct and incorrect operation and manipulation in every detail.

He must also be able, promptly, to size up an operator as to his standing in his class, as to slow, medium fast, fast, or extraordinarily fast and expert. With this ability he can, after gaining sufficient experience, with almost equal satisfaction arrive at correct minimum unit times for equitable

rate setting, no matter what grade of operator he may observe. However, it is at all times easiest and best to make observations on a first-class, *but not extraordinarily expert,* operator.

It is because Mr. Merrick was a full-fledged machinist of several years experience before he, some eighteen years ago, took up with time studies and rate setting as his specialty, under my own direct supervision and Doctor Taylor himself as the supreme leader, that I have such confidence in his work in this field that I have always refused to *break in* other men to make time studies and set rates for my own clients, and insisted that this be turned over to Mr. Merrick whenever he has been available.

It is also because of this that I express my confidence that what Mr. Merrick has to offer the reader in this volume is of real value.

CARL G. BARTH.

BUFFALO, N. Y.
February, 1919.

PREFACE

THE purpose in preparing this book on time studies for rate-setting is to contribute something toward satisfying a great need of industrial management that was first pointed out by Dr. Frederick W. Taylor as far back as 1895. If any proof is needed as to the interest of industrial executives and mechanical engineers in this topic at the present time, it is amply supplied by the remarkable response aroused by the author's articles printed in *Industrial Managament*, beginning with June, 1918, which form a portion of this book.

Doctor Taylor's great contribution to human progress consisted in pointing the way to raising human labor to a higher degree of productivity, and thereby to increased earning power. Upon this his fame rests securely as one of the great leaders and greatest Americans of the Nineteenth and Twentieth centuries. In his two books, "The Principles of Scientific Management" and "Shop Management," he laid down his philosophy and principles of industrial management. In his presidential address before The American Society of Mechanical Engineers on "The Art of Cutting Metals," he gave the results of the most extensive and exhaustive series of experiments ever conducted on any subject relating to the metal-working industry. Second only in extent to his researches in metal cutting, was his investigation of the principles of and the formulation of the practice of scientific time study. It was the author's good fortune to be associated with Doctor Taylor in this work from 1898 to the time of his death.

The beginnings of time study date back to 1881, when Taylor was foreman of the machine shop of the Midvale Steel Company of Philadelphia. He recognized that it would be more accurate to time each element of the various kinds of work to be done with a stop-watch, and then find the quickest time in which each job could be done by summing up the total times of its component operations and adding a reasonable percentage of allowance, then to search through records of former jobs as a guide in judging of the proper time and price. After two years of experimentation and trial he was convinced that this method of time study was a success. In regard to its success he wrote:

"This department far more than paid for itself from the very start; but it was several years before the full benefits of the system were felt, owing to the fact that the best methods of making and recording time observations, as well as of determining the maximum capacity of each of the machines in the place, and of making working tables and time tables, were not at first adopted."

It is so easy to overlook a purpose amid the details of its execution that many in the past may have considered accurate time study as theoretical, and as failing to hold concrete advantages in shop management. For the benefit of all such it is well to state again the purpose of time study for rate-setting, essentially as worded by Doctor Taylor many years ago: "Time study for rate-setting is the means to attain the fundamental objects in manufacturing, of high wages and low labor costs."

The reason for the need of time study is found in the lack of knowledge by workmen, foremen and employers as to the time in which work can and actually should be done. The first-class mechanic knows that he can do more than the average, but very rarely does he know how much his increase of production might be, unless he has in some manner carefully studied the operation. Yet a wealth of experience from time-study work shows that a first-class man can do very substantially more than the average and keep his pace up indefinitely without injury to his health, and the consciousness of more and better production and the increased earnings that go with the larger output, brings a happiness and zest in work not felt by those working under other conditions.

A striking example of this proof occurred in the experience of the author when the workmen of one large department in an industrial plant complained of unfair treatment. Other departments in this same establishment were working under rates set by time studies, and the men of this particular section felt that they were unjustly handicapped in production and earning power because their operations had not been similarly studied and rated.

The application of time study is as wide as manual operations in industry. Detailed times are given in this book for several distinct kinds of work, including machine-shop operations, molding, unloading freight-cars, cleaning windows, and carting bricks, stone, sand, ashes, coke and coal.

The art of taking time studies has its difficulties, like all others. A parallel that has often been used is in drafting. Should a shop manager determine to establish a drafting-room

where none existed before, he would understand at the outset some of the troubles that he would have to face and overcome. At the first he would not expect much success, even if he should establish his department by hiring experienced draftsmen and designers. The difficulties would be greatly increased should he be compelled to start his drawing-room with men who did not understand the art of drafting, even though they might otherwise be capable and energetic. So, in undertaking time-study work, progress must of necessity be slow at the outset, for it is an art that has its own methods, implements and practice, gathered through years of patient research and experience.

One purpose of this book is to lay down in amplified form the principles covering time study for rate-setting, to show numerous mechanisms that have been found helpful in taking observations and using detailed times as determined, and to present some details of practice, particularly in regard to the human relationship involved in the work, such as only experience can point out.

This volume is divided into three sections: The first presents the principles, methods and implements of time study; the second is an illustration of time study as applied to a line of machine tools—Gisholt boring mills—together with a series of tables giving the detailed times as established by study; while the final section, in the nature of appendices, includes detailed times for a number of other kinds of work, and thus shows conclusively the wide adaptation of the principles and methods outlined.

Accurate time study is a contribution to industry at large, but, as the majority of our industries utilize machinery, it is natural that the majority of the examples presented have been drawn from the machine shop. In this connection the distinction should be fully appreciated between the study of an individual operation on hand-work, or on a machine, and a study of the operation of the machine itself. The first type of study would be represented, for instance, by a profile cut on a rifle part, while the second would be the study of the elementary motions in connection with the operation of a machine tool, such as a boring mill. The difference between the two classes of studies is at once apparent, for the first applies to work on a particular piece only, while the latter supplies information for fundamental operations on a given machine, and in this form the data may be used for all work within the capacity of the machine tool.

The examples of this latter class of studies given in this book, namely complete time tables for a line of boring mills, are the first of their kind to be published. But their value is so great in its influence upon machine tool operations and the method of determining the production from them, that it is the hope of the author that in time every line of standard machine tools will be similarly studied, and whenever such a machine goes into service there will be supplied with it a complete set of individual times for its various operations.

The preceding paragraphs have fully pointed out the credit due Doctor Taylor in connection with the topics of this book, while it is a privilege to acknowledge the opportunity afforded the author to enter his career as a time-study expert at the Link Belt Company under the personal direction of Carl G. Barth, and his advice and constructive criticism when introducing methods at the plants of the Watertown Arsenal and the H. H. Franklin Manufacturing Company. Acknowledgment is also made of the unparalleled opportunities afforded in the development of time study and the introduction of the author's methods of rate-setting at the plant of the Winchester Repeating Arms Company, by the management of that plant, the accurate production demands caused by the war, and the variety of occupations studied and rated to the satisfaction of both the management and the twenty thousand employees affected.

In addition, the author wishes to acknowledge the assistance of others. He is thus indebted to the wise counsel of Mr. Edward W. Clark, 3d, Mr. Morris L. Cooke, Colonel H. K. Hathaway, and Lieutenant-Colonel Sanford E. Thompson in planning the general lines that have been followed in the preparation of this volume; to the additional assistance of Mr. Robert T. Kent, who prepared a portion of the introductory matter that appeared serially in a few articles in the *American Machinist* during 1917; to Mr. L. P. Alford, who, as editor of the former publication and later editor of *Industrial Management*, was largely responsible for the success of the articles in those magazines; and finally to Mr. Reginald Trautschold, who has done the editorial work in preparing this volume for publication.

DWIGHT V. MERRICK.

NEW YORK, N. Y.
February, 1919.

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CHAPTER I

OBJECTS AND PRINCIPLES OF TIME STUDY

ANY piece of work, any task, entails three fundamental considerations: with what implements it is to be performed; how it is to be done and the length of time required for the performance of the task. The last, the time required, is the all-important consideration in any industrial pursuit, for it is the measure of production, the gauge of the result. How or with what it is done is quite immaterial, provided the task is accomplished expeditiously and economically—in other words, with a minimum expenditure of time and energy. Results are what count, but results can only be secured if the tools are suitable and kept in effective working order, and the process employed, or method of performing the work, is efficient. To set a rate at which work should be performed or to establish a standard period in which the task should be completed, necessitates, then, a preliminary standardization both of the implements to be employed and the method to be followed, and no standard rate can be established unless these two preliminary steps are taken first. Of an investigation aiming to increase production, it is quite as much a part to standardize ways and means as it is to set a rate at which the work should be performed.

An investigation to increase output calls for time study, for it deals primarily with the element of time, so time study has for its objects: (1) the determination of possible improvements in the equipment and surrounding conditions for producing a given piece of work, or for discharging a specific piece of work; (2) the determination of possible improvement in the method of actually performing the work; and (3) the determination of a unit time in which a given piece of work, or task, should

be finished, under satisfactory conditions with effective use of the equipment provided for the task. Properly speaking, the main object of time study is to determine the time for a task, the first two enumerated objects being rather of the nature of analysis and simplification of the motions preparatory to time study—in reality motion study.

Time study is essentially constructive in its function, for its ultimate objective of arriving at a fair and equitable rate at which the work should be done is reached only after each act and mechanism incidental in any way to the completion of the work has been carefully analyzed and made as convenient and easy as possible for the operator—all unnecessary work eliminated and all acts essential to the conduct of the work simplified.

A detailed analysis of all the elements that enter into the completed task is made and the most effective method of operation determined in advance. In this way a clean cut science is developed for each and the aggregate of the element operations, the operator trained and taught to work in an effective and predetermined manner, the responsibility for which rests with the management, so that his energies are expended in a way highly profitable to him and to his employer. The fundamental principle underlying time study is that the greatest material gain to the employer is possible only when the employee gains correspondingly and the responsibility is divided equitably between the management and the worker. Time study imposes upon the management the responsibility for the work and, with the co-operation of the workers, the task of training them in the operating methods developed. Upon the workers is imposed the obligation of learning how to perform work in the most effective manner, by following the plain and simple instructions which are an intimate and inherent part of time study.

No time study should ever be taken without first thoroughly acquainting those who are in any way connected with the work that is to be studied, and especially the one person that is to be observed, with the object of time study and the benefits that will be derived therefrom; and every effort should be made to gain the confidence and full consent of the worker. In some establishments time study has been brought into disrepute because it has been sprung upon workmen without any effort to obtain their co-operation.

Time study procedure entails certain basic investigations which are essential before the data collected can be made use

of in rate setting. There should be made, first, a careful survey of the work and all influencing conditions; second, an analytical division of the task into simple elements; third, an observation and record of the time taken in performing each of the element operations; and, fourth, an analytical study of the recorded unit times. To make use of the data collected for rate setting, all abnormal readings should be eliminated and a fair standard time determined upon for each one of the simple operations—due and fair consideration being given to the character of the work and the demands upon the operator. Fair allowances to be made for fatigue and unavoidable delays in the course of the work should be ascertained and, finally, there should be prepared a plain instruction card from the time-study records, to include the measured allowances for fatigue and the interruptions to be anticipated which are beyond the control of the operator.

The taking of time studies calls for an observer—the person making the time study—of an analytical turn of mind, skilled not only in making time studies, but also in the character of the work under observation, though not necessarily a skilled operator—worker—on the task in question. The observer should be somewhat of a psychologist as well, for he must have a clear conception of the frailties and limitations of human nature in order to make just demands upon the operator in setting tasks.

The operator should be advisedly a first-class worker, skilled in the line of activity under investigation, and of somewhat better than average ability, for the fatigue and other time allowances added to the specific times recorded during the study should be so proportioned as to bring the resulting rates within the range of ability of the average worker. When the services of an operator with such ideal qualifications cannot be secured for a time study, an experienced observer can arrive, not infrequently, at as accurate deductions from which to set an equitable and fair rate by a study of a quite mediocre worker. In such instance, greater dependence upon the skill and experience of the observer is necessary than if the operator is a highly skilled worker co-operating with the observer in establishing a standard time for the work.

The experienced observer, acquainted with the character of the work, with effective and efficient methods of performing simple manual and mechanical operations and who is also a keen student of human nature, soon learns to recognize with certainty any tendency on the part of the operators not to do

their best and to make due allowances for the resulting inefficiencies, etc. Unusual ability and excessively rapid movements on the part of the operator, that is, dexterity and speed of action which could not be maintained without causing physical exhaustion, are also apparent to the trained observer and are properly discounted by him, for the desired task time is the one that can be equalled by workers following instructions and working at a reasonable pace—a pace which can be kept up from day to day without undue exertion.

Prior to commencing a time study, it should be an invariable rule that the observer acquaint himself with the character of the work and with all the conditions which affect or may affect it. He should observe the conditions under which the raw material is furnished to the operator and the facilities that the operator has for disposing of his finished product. He should familiarize himself with the quality of work demanded, including the degree of finish and the limits of accuracy required. He should see that the necessary equipment for the operator effectively to perform his work is provided and available as required and, if the study is on a machine operation, he should see that there is a sufficient supply of power to drive the machinery to the best advantage. If, during this preliminary survey, it appears to the observer that certain conditions are abnormal, they should be rectified before any attempt is made to start time studies. It is essential that the observer should aim to establish standard conditions, which can be repeated at any time in the ordinary course of work, and the best sequence of events in the conduct of the work.

The time required for the performance of any piece of work or definite task depends upon two groups of factors—those within the control of the operator and those over which he personally has no control. The first group consists of the handling of the work at his machine or place of work and the manipulation of the necessary tools and aids. The second group includes the supply, quality and quantity of raw material, the tool equipment and all implements which should be furnished him for the effective conduct of his work. Time study is applied to the acts of the first group, but it is futile to expect any marked improvement by means of time study on the various operations unless means are provided to control adequately the items of the second group.

The time studies necessary to the effective operation of any particular establishment may be taken in two ways: (1) If the product does not vary in type and character from day to

day and is made by repeating the same operation or set of operations, it probably will be wise to take a study of each operation as a job complete in itself. Such investigations are known as operation time studies. (2) If the product varies frequently, and is made by a series of unrelated elementary motions, the grouping of which is never, or seldom, the same, it is necessary to determine which of the several elements are to be grouped and regrouped to perform the various fundamental operations. Time studies should be taken on the individual fundamental operations either singularly or collectively, and the data thus secured can be arranged and combined in such manner as to fix a definite time for the performance of practically every job that may be performed in the establishment. Such studies are usually conducted on machine tools or on complete operations, where elements from several fundamental operations can be taken to make up a new fundamental operation and these made into a complete operation. Such studies would be known as fundamental operation time studies.

The method of observing and recording the time required to perform particular operations and the study and analysis of the required data is, as a rule, the same for both operation time studies and fundamental operation time studies.

The first step in the taking of a time study is the analysis of the job as a whole into its elementary divisions. The observer lists these divisions of the work in the order of their occurrence, splitting the job up into a greater or less number of more or less minute elements, depending upon the character of the work and the conditions surrounding it. It may be desirable or necessary in certain cases to analyze each operation down to the most elementary unit, while in other classes of work it would be perfectly satisfactory to group several such minute elements together to form a subdivision of the whole operation. For instance: In studying the operations in a lathe, a cutting tool would be inserted in and removed from the tool post several times during the course of the work. If a study is being made to determine the length of time required for certain cutting operations, that is, if we are studying the work itself and not the machine in which the work is being done, it probably would be sufficient to enter the time required for inserting the tool in the tool post as a single item; viz.:

Put tool in post..0.30 min.

On the other hand, if we are studying the lathe with a view to determining the best method of handling it and the tools

pertaining to it, it would be desirable to analyze this operation of putting the tool in the tool post still further as follows:

Get tool from tool stand	0.03 min.
Measure height of tool	0.06 min.
Put packing in tool post	0.07 min.
Put tool in post	0.03 min.
Set tool in position	0.03 min.
Tighten tool-post setscrew	0.08 min.
Total	0.30 min.

In general, the following rule may be established for grouping the elements: When the time intervals of the individual elements are extremely small, it is best to group them and treat the combination as a single element. There are several reasons for this, chief among them being the difficulty of accurately observing and recording the items that follow each other with an interval of only a few hundredths of a minute between. An error in reading the stop watch may easily equal the elapsed time for the performance of the particular element under observation. If it is absolutely necessary to obtain the elapsed time of each small element, this may be done if the work consists of recurring cycles of specific operations, though the duration of the individual operations is so short as to make it difficult, if not impossible, to obtain accurate readings on the watch for the elementary acts. Where several successive short elementary operations are repeated continually, it is possible to take the time for various groups of observations which occur in regular order, and from the data thus obtained to calculate the time of each element—provided, the number of successive elements observed as a unit is prime to the total number of element operations in the complete cycle, as demonstrated by Carl G. Barth and first mentioned in Mr. Taylor's book, "Shop Management."

The observing and recording are done with the aid of a stop watch whose dial is divided into one-hundredths of a minute, the hands of which are so arranged as to permit of their being stopped and restarted from the same point without being set back to zero, if desired. The observation sheet is usually carried on a board that has a pocket on the upper edge into which the stop watch fits. The board is of such size as to conveniently be carried upon the observer's left arm, and the position of the watch is such as to bring the work, watch and observation sheet in the same straight line with the observer's eye.

CHAPTER II

TAKING AN OPERATION TIME STUDY

THE detailed procedure followed in taking an operation time study is well exemplified by the method in which collection of necessary data to establish a standard time for performing the operation of edging, or profiling, the bolt breech of a military rifle was conducted. The importance of establishing a definite and effective rate for this operation may be appreciated from the fact that the same operation, performed in the same manner and with the same tools, is to be performed hundred of thousands of times.

The observer, after familiarizing himself with the operation, tools and all conditions influencing the work, systematically records the information upon an observation sheet, a standard form of which is shown in Fig. 1. In the space at the top of the face sheet are recorded the data necessary to the identification of the operation, the machine, etc., and on the reverse side (Fig. 2) are noted the details of speeds, feeds, material used, etc.; sketches are made of the piece of work and the tools; and all other information is recorded that may prove useful to the observer in working up his observations after he has left the machine at which the study was made.

It will be noted that the reverse side of the observation sheet carries printed notations of the subjects on which information should be secured when the time study is taken. It has been found advisable to have these printed memoranda, for the reason that if the time-study man trusts to his memory, he will frequently overlook one or more important items. Such oversight would necessitate a second trip to the job, or the omission of the information altogether, as often as it cannot be secured after the job has been completed and the set-up for it dismantled. When the items that must be observed are printed, and the observer is required to make an entry of one kind or another opposite each item, it would be an exceedingly careless time-study man who would leave the job without complete information. The notes and data recorded should always be as full and definite as conditions permit, for it should always be possible from the information recorded on the observation sheet to reproduce the conditions under which the study was made.

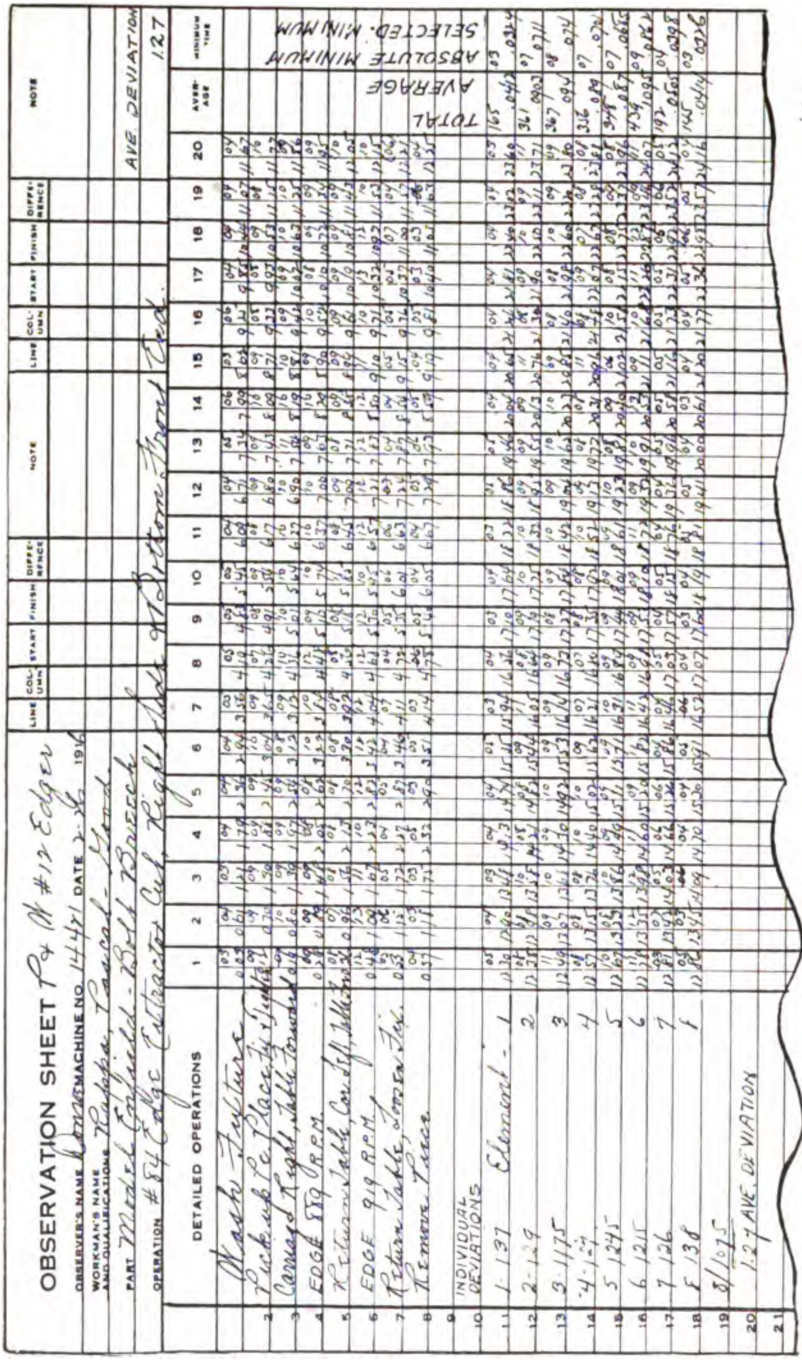
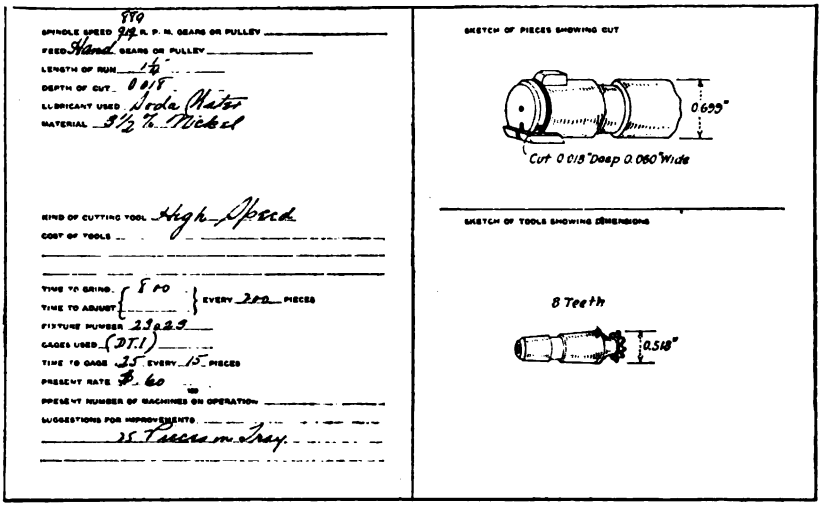


FIG. I.—SPECIMEN TIME-STUDY OBSERVATION SHEET


SPINDLE SPEED 919 R. P. M. GEARS OR PULLEY
FEED Hand GEARS OR PULLEY
LENGTH OF RUN 1½"
DEPTH OF CUT 0.018
LUBRICANT USED Soda Water
MATERIAL 3½ % Nickel

KIND OF CUTTING TOOL High Speed
COST OF TOOLS

TIME TO GRIND 8.00 } EVERY 200 PIECES
TIME TO ADJUST
FIXTURE NUMBER 23a23
GAGES USED (DT.1)
TIME TO GAGE .35 EVERY 15 PIECES
PRESENT RATE $.60 / 100
PRESENT NUMBER OF MACHINES ON OPERATION
SUGGESTIONS FOR IMPROVEMENTS
25 Pieces in Tray.

SKETCH OF PIECES SHOWING CUT

SKETCH OF TOOLS SHOWING DIMENSIONS

FIG. 2.—REVERSE OF TIME-STUDY OBSERVATION SHEET

In the study under consideration, the observer analyzed the profiling of the bolt breech into eight elementary operations. These are listed in the column at the left of the operation sheet and in the spaces following the entries will be noted two sets of figures. Those in the lower part of the space are the "continuous times," recorded as the study is made. The observer may at the conclusion of his observations on the first piece set his watch to zero and record the details of the second piece without reference to those of the first, but it is more desirable to allow the watch to run continuously and to make all observations show the elapsed time from the beginning of the study. This was what was done in the present case, and it will be noted that the recorded times are continuous from one series of operations to the next. If during the progress of the time study, an interruption not connected directly with the work occurs, the watch may be stopped and restarted from the same point when work is resumed. In other words, the observer notes only those events that have a direct bearing on the work.

It is better, however, to allow the watch to run, and to make a notation in one of the spaces at the top of the sheet, giving the time at which the interruption began and the time at which it was ended. The advantage of this is that there would be at the end of the time study a complete list of all such interruptions to the smooth progress of the work as might reasonably be expected and for the prevention of which provision could be made in subsequent work.

The number of complete operations that should be observed during a time study will vary with the nature of the work. If a comparatively long period of time is required for each of the elementary operations and it is evident that the operator has obtained a rhythm that enables him to work at an approximately uniform rate, then a comparatively small number of observations will suffice. In explanation, the same time for a given error in a long element as compared with a short element would show up a larger percentage of error in the work, thus necessitating a greater number of observations than when the element is long. The best results will be obtained if the operator is permitted to work a sufficient length of time to attain his rhythm before the observations are commenced. On the other hand, if the element operations are all of short duration, introducing the possibility of errors in the reading of the watch, or if the operator shows that he is not proceeding uniformly as regards speed of working, a large number of observations must be made. The requisite number of observations is a matter which has to be left to the judgment of the time-study man. As a general rule, where the average duration of the element operation is less than one minute, twenty complete operations, however, should be made.

On the completion of the observations at the job, the observer determined the "individual time" for each element operation from the "continuous times" recorded while taking the study. These individual times are the times required for the completion of each of the several elements, and are entered on the observation sheet opposite the particular element involved and above the record of the "continuous" or elapsed time made while the time-study observations were under way—see Fig. 1.

Taking now, for example, the seventh detail operation, "Return Table," we have a set of values ranging from 0.03 to 0.07 min. as the time for performing this operation on the 40 pieces on which the time study was taken. The item 0.03 min. in line 17, column 1, in the second, or lower, group is stricken out as being due to an error or an abnormal condition and the remaining times are averaged, the average value 0.0505 being entered in the column allotted for that purpose.

The striking out of abnormal values, either excessively higher or lower than the average of all the individual times of the same element, is a detail that calls for fine judgment on the part of the time-study man. Such variations may be due to an error in reading the watch, or to an abnormal condition of the work that is not likely to recur in the ordinary course of events.

While no general rule can be laid down for the elimination of these abnormal items, minimum or maximum isolated items 25 per cent. less or 30 per cent. greater, respectively, than an adjacent item should usually be rejected.

Having determined the average, the abnormal readings being eliminated, the individual times used in determining the average are scanned and the minimum individual time ascertained. This is divided into the average, the quotient being designated as the "deviation." The above procedure is followed for each of the detail operations, and the individual deviations are listed as shown on the observation sheet. These are then totaled and divided by the number of deviations. This quotient, usually, though incorrectly, called the average deviation, is a factor that divided into the average of the individual times for a detail operation will give the "selected minimum" time for that operation. The "total selected minimum," or cycle time, is not the time in which it is expected that the cycle be performed in practice, although some one or more of the elements of the cycle might be performed within their respective "selected minimum" times by an exceptional operator working under unusually favorable conditions.

In many cases the deviations of the several elements of a cycle show quite wide variations. The deviation factor reconciles these variations and furnishes a convenient way of reducing the several averages to a common standard. It also takes into consideration the influence that the several items in a cycle may have on any particular item. The value assigned to an item considered by itself may be quite different from the value it would assume when it is considered as a part of a series of items.

A shorter method of finding the deviation factor is to divide the sum of the averages by the sum of the minima. It is, however, desirable to note the fluctuations of the several individual deviations from the deviation factor, since those elements that show the widest deviation are those upon which the greatest improvements may reasonably be expected.

In cases where the very nature of the work has a tendency to vary the elementary motions and they are not of sufficient importance to warrant an attempt at improvement the shorter method will save time.

A large number of studies seem to indicate that the "selected minimum" times for the various elements as determined from observations on one operator will agree closely with those obtained from observations on another operator doing the same class of work. This is true, even if the corresponding elemen-

tary average times for the two operators show an aopreciable variation.

In analyzing a study, the deviations of the motions of a similar nature are, strictly speaking, comparable. In explanation: It is obvious that all operations consist of one or more major elements and the handling elements involved in their performance. It is often advisable to group the deviations of the major elements together and also those of the handling elements, the group averages of which should then be applied to the respective elements from which the group deviations were derived. At times it may even be necessary to make finer subdivisions of the elements, as, for instance, when the elements are of a decidedly dissimilar nature.

The deviation in reality is the amount an operator varies from perfection—a 100 per cent. operator would have a deviation ratio, or deviation, equal to unity, for a hundred per cent. operator is one whose average time for a task equals the minimum selected time for the work. A power-feed machine time where the speed is kept constant would show a deviation equal to one.

Observations have shown that average operators working in good rhythm show a deviation ranging between 1.20 and 1.30. Deviations as low as 1.15 have been obtained, usually on short cycle operations where women are employed.

From a number of studies taken on men, it is observed that they rarely show a deviation lower than 1.20. This can be explained in part by the type of work they usually perform. Studies showing deviation much above 1.30 are questionable and should be carefully considered before use is made of them.

Judgment should be used by the observer in taking a study to note if the operator is working at his best pace, for it is possible for experienced operators to time themselves so dexterously as to be able to bring about a low deviation.

It is evident from the foregoing that the selected minimum elementary time as determined by the time study represents an exceedingly high standard of performance on the part of the operator. It would be unfair and unwise to expect the operator to continue at such a rate throughout the day without any rest or relaxation. In fact, *it is not expected that an operator will attain the minimum time*, except under unusual circumstances. Therefore, in setting tasks or writing instruction cards from the data gathered by time study, an allowance is made to bring the time for a job within the ability of the average first-class workman. This allowance is a percentage of the

sum of the elementary times that enter into the operation. It depends both upon the nature of the work and on the amount of work in a single complete operation or cycle of operations.

Based on the data from a vast number of time studies on a great many varieties of work the curves in Fig. 4 have been derived. These curves are a guide to the percentage that should be added to the sum of the times of the elements making up an operation. The curves show the allowances that should be made for several classes of work, the differentiation between these classes being the relative percentage of machine time and handling time in the operation. The mathematical expression of these curves were derived by Carl G. Barth.

The deductions made by the observer from his analytical study of the data recorded at the job are summarized and entered on a second observation sheet (Fig. 3) on which are

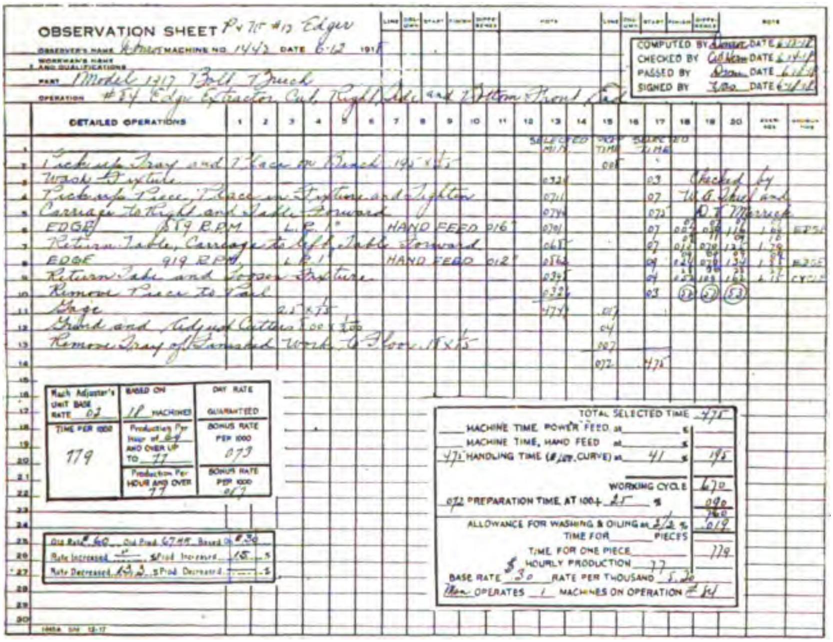


FIG. 3.—SUMMARY OF TIME STUDY RECORDED IN FIG. I

three columns, headed "Selected Minimum," "Preparation Time" and "Selected Time," respectively.

The figures under "Selected Minimum" are derived from the time study as previously explained, and appear on the face sheet only to show the source from which the "Selected Time"

is obtained. Both "Selected Minimum" and "Selected Time" agree in total, the only difference being that the individual selected times are simplifications of the individual selected minimum times.

In the "Preparation Column" is placed the time for doing certain operations which are not performed regularly, and these are shown on the numbered lines, 2, 11, 12, 13. The time allowed for performing these operations is standard, being arrived at by previous time study and, in some cases, is more or less liberal. The time allowed for each operation is divided by the number of pieces done during certain intervals to obtain the allowance per single piece.

Inasmuch as this job includes only handling time, Curve 100, Fig. 4, is used to determine the percentage of allowance. The percentage, 41, is found at the point on this curve corresponding to the time of the selected cycle, 0.475 minute. Multiplying the selected cycle of 0.475 minute by 0.41 we obtain an allowance of 0.195 minute. This is added to the selected cycle and gives a total of 0.67 minute for the working cycle. The working cycle is the time in which the operator should perform the operation consistently over a full working period.

To the preparation time an arbitrary allowance of 25 per cent. is made to offset any variation, interferences, etc. To the total of working cycle time and preparation time a flat shop allowance of 2½ per cent. is added to cover oiling the machine and washing at noon and night. The grand total, 0.779 minute, of the several items enumerated is the standard time in which the workman should do the job.

Before the rate established by the time study is put into effect in the shop, it is checked by observing the workman assigned to the work for a few cycles of the operation and noting whether he approaches the selected minima of the detail operations. Any appreciable variation indicates an error in the time study, one which should be corrected before the study can be accepted. A satisfactory check is followed by the insertion on the summarized observation sheet of the various items of hourly production, wages, rate, etc., relating to the operation studied. Instruction cards, one for the machine adjuster (Fig. 5), whose duty it is to adjust, maintain in good operating condition and inspect the machine to be employed, to see that it is properly lubricated, to secure the cutting tools, etc., and to exercise supervision over the machine; and the other (Fig. 6) for the workman assigned to the job are then compiled. The latter instruction card should carry detailed instruction of all

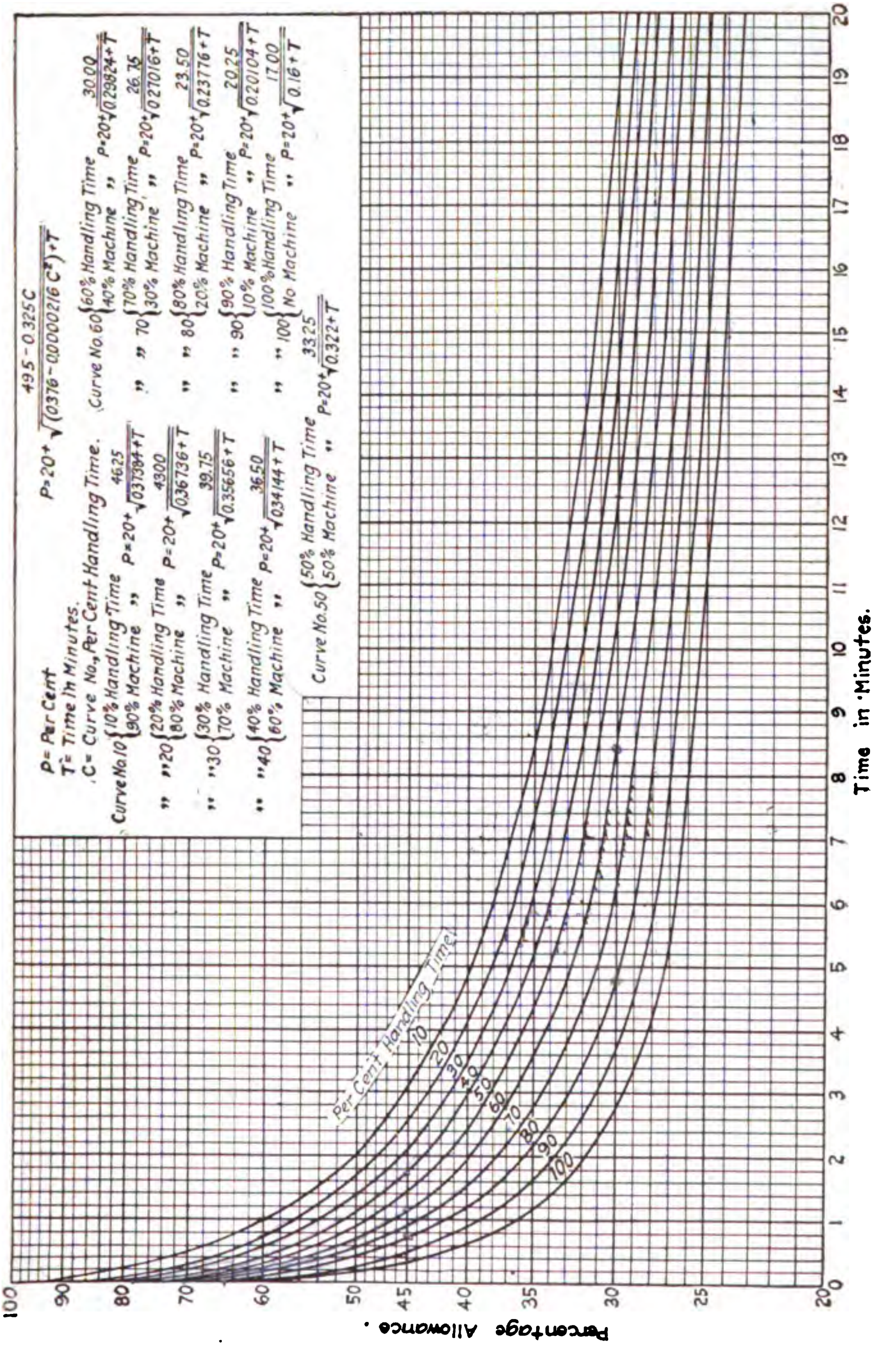
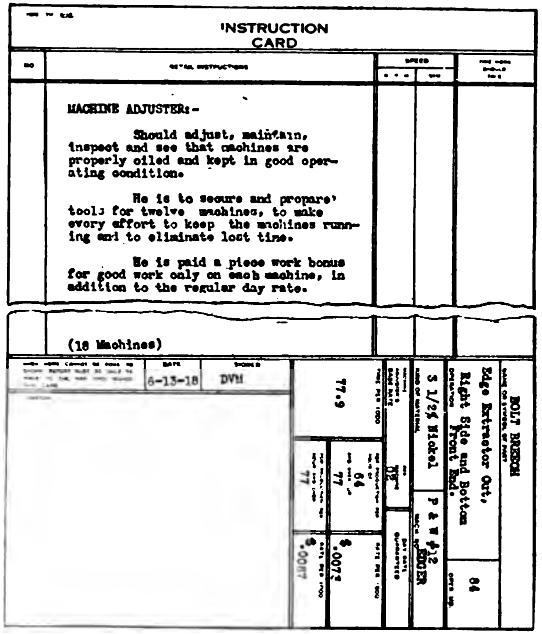


FIG. 4.—CURVES OF DELAY ALLOWANCES



INSTRUCTION CARD

MACHINE ADJUSTER:-

Should adjust, maintain, inspect and see that machines are properly oiled and kept in good operating condition.

He is to secure and prepare tools for twelve machines, to make every effort to keep the machines running and to eliminate lost time.

He is paid a piece work bonus for good work only on each machine, in addition to the regular day rate.

(18 Machines)

BOLT BREECH

Edge Extractor Out, Right Side and Bottom Front End.

84

3 1/2% Nickel

P & W #12 EDGER

02

77.9

64

77

$.0073

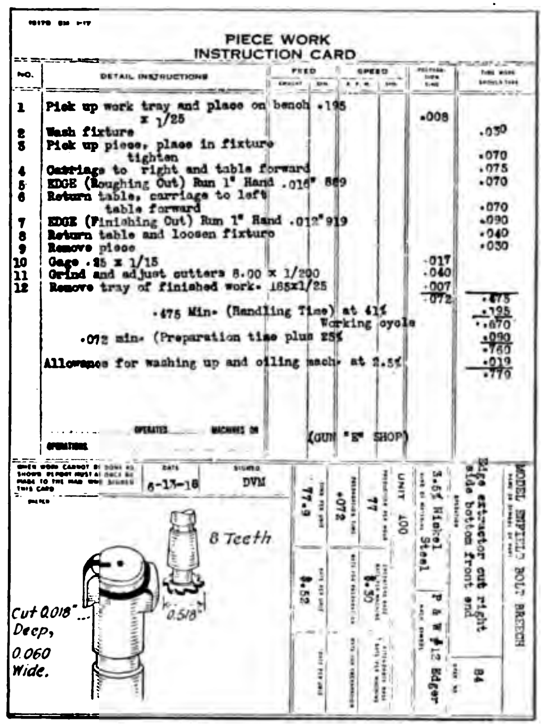
77

$.0087

6-13-18

DVM

FIG. 5. INSTRUCTION CARD TO MACHINE ADJUSTER



PIECE WORK INSTRUCTION CARD

NO.	DETAIL INSTRUCTIONS		TIME
1	Pick up work tray and place on bench .195 x 1/25	.008	
2	Wash fixture		.030
3	Pick up piece, place in fixture tighten		.070
4	Carriage to right and table forward		.075
5	EDGE (Roughing Out) Run 1" Hand .018" 889		.070
6	Return table, carriage to left table forward		.070
7	EDGE (Finishing Out) Run 1" Hand .012" 919		.090
8	Return table and loosen fixture		.040
9	Remove piece		.030
10	Gage .25 x 1/15	.017	
11	Grind and adjust cutters 8.00 x 1/200	.040	
12	Remove tray of finished work. 185x1/25	.007	
		.072	.475
	.475 Min. (Handling Time) at 41% Working cycle		.195
			.670
	.072 min. (Preparation time plus 25%		.090
			.760
	Allowance for washing up and oiling mach. at 2.5%		.019
			.779

(GUN "E" SHOP)

MODEL ENFIELD BOLT BREECH

Edge extractor cut right side bottom front end

84

3.5% Nickel Steel

P & W #12 Edger

UNIT 100

77

$.30

.072

77.9

$.52

6-13-18

DVM

8 Teeth

0.518"

Cut 0.018" Deep, 0.060 Wide.

FIG. 6. INSTRUCTION CARD TO OPERATOR (WORKMAN)

acts necessary for the workman to perform, with entries of the time the work should take and, in addition, the calculated "handling time" and the allowance for washing up, oiling the machine, etc. The sum total of the element times, handling time and allowances establishes the time per unit upon which the rate per unit is figured.

In the shop in which the time study on profiling the bolt breech of the military rifle was taken, a guarantee of the rate of payment is also issued with the instruction card to the workmen (see Fig. 7). The late Dr. Frederick W. Taylor always re-

GUARANTEE OF RATE

GUN "E" (SHOP)	BOLT BREECH (NAME OF PART)		1917 (MODEL)
84 (OPER. NO.)	EDGE EXTRACTOR CUT. RIGHT SIDE AND BOTTOM FRONT END (OPERATION)		77 (PROD PER HOUR)
P. & W. NO. 12 EDGER (MACHINE)	$0.30 (BASE RATE)	$0.52 (RATE PER 100)	6-13-18 (DATE)

The above Piece Rate depends upon the Base Rate and the Time allowance for doing the Work.

The Base Rate is determined by Business and Industrial Conditions.

The Time Allowance is determined by Time Observations.

The Company guarantees that the Base Rate will not be Changed as long as there is no Radical Change in the Business and Industrial Conditions, and Guarantees that the Time Allowance will not be Changed as long as the Method Described on the Instruction Card is in Effect.

JOHN DOE MANUFACTURING CO.
PER · D

FIG. 7. WORKMAN'S RATE GUARANTEE

garded the issuance of an instruction card to the workers as a guarantee of the task time for the performance of the work as described, but the separate guarantee, suggested by J. E. Otterson of the Winchester Repeating Arms Company, is not without merit.

CHAPTER III

TAKING A PRODUCTION STUDY TO CHECK TASKS

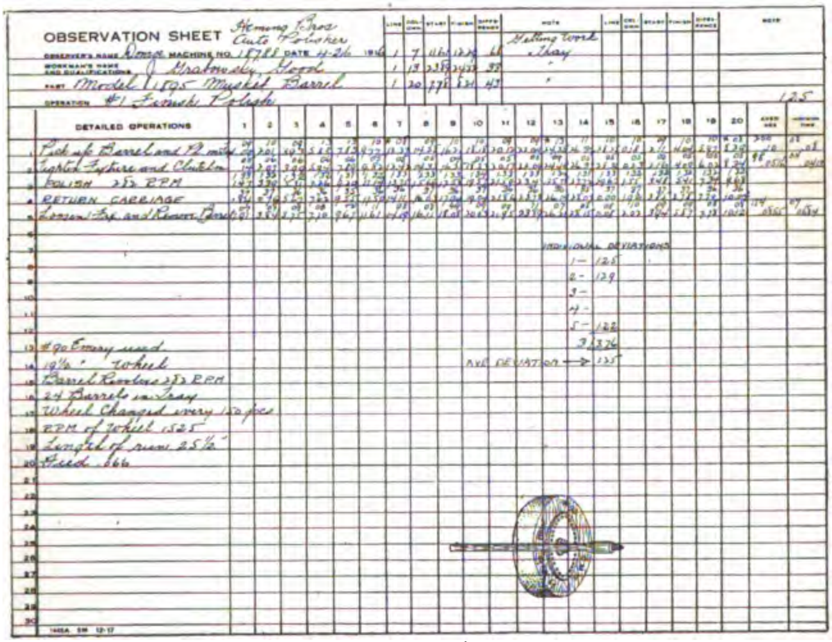
AFTER an operation time study has been completed, an instruction card prepared, and a rate set, there is sometimes complaint made that the operator is unable to reach the standard called for by the instruction card. This may be due to one or more of several causes: Lack of skill on the part of the operator; trouble with the machine; improper equipment; unnoticed or unnecessary delays or wastes of time; or an incorrect time study.

If an operator consistently fails to perform his task in the allotted time, it is essential that his work be studied to ascertain which of the above enumerated items is the cause of the failure. If the fault lies with the operator, he may be corrected or put under instruction. If the machine is out of order, the necessity of repairs or adjustment becomes at once apparent. If the time study has been carelessly or incorrectly made, that fact will be revealed and the rate called for by the instruction card can be canceled pending the correction of the study and the establishment of a new rate. It should be said here that when the original time study is made and computed according to the methods previously described, the rate will seldom be found to be incorrect, but that the trouble lie with the machine or the operator. The study that is made to determine the cause of failure of an operator to reach the standard set is known as a "production study."

A production study consists in an observation of a job during its entire course, the time of the various elements or cycles of elements being taken, together with the time of all interruptions or delays of any kind whatever. The production study should begin preferably when the operator starts work in the morning and should continue throughout the day, or possibly for several days, provided the job lasts that long, and the nature of the work requires it. It is especially desirable that the study continue for an entire day if the work is of such a nature as to require considerable exertion on the part of the operator, in order that the effects of fatigue may be determined. It often happens

that a time study which is apparently correct for jobs whose duration is but an hour or two will set a task which is far too severe if the job is to be continued for eight or ten hours by reason of the cumulative effect of fatigue over the longer period.

In making the production study, the watch should be started at the commencement of the work and allowed to run continuously until the study is completed. The observer should notice the elapsed time at the completion of each element operation or cycle and at the beginning and end of each interruption the class of the work and the nature of the interruption or delay. The observer should take differences—determine the individual times—during the course of the study, if the intervals between readings are of sufficient duration to permit so doing. The taking of differences on the spot supplies the data necessary for


OBSERVATION SHEET

DETAILED OPERATIONS

1 Pick up Barrel and [illegible]
2 Tighten Fixture and Clutch
3 POLISH 252 RPM
4 RETURN CARRIAGE
5 Loosen Fix. and Remove Barrel

INDIVIDUAL DEVIATIONS
1 – 125
2 – 129
3 –
4 –
5 – 122

AVE. DEVIATION → 125

13 #90 Emery used
14 19½" wheel
15 Barrel Revolves 252 RPM
16 24 Barrels in Tray
17 Wheel Changed every 150 pcs
18 RPM of wheel 1525
19 Length of run 25½"
20 Feed 166

FIG. 8.—TIME STUDY ON POLISHING A RIFLE BARREL

the observer to make frequent comparison of the several individual times, practice which frequently enables the observer to detect discrepancies in the operator's work and to determine and apply the remedy at once.

At the conclusion of the production study, the time consumed in the several operations and by the various delays is summar-

ized and totaled. This collection of data will then make it a simple matter to determine whether the workman wasted time or was subjected to unnecessary delays in securing materials, etc., whether there were machine delays and whether the machine was run at the most effective speed.

Figs. 8, 9 and 10 illustrate a time-study observation sheet, its summary and the instruction card issued to the workman

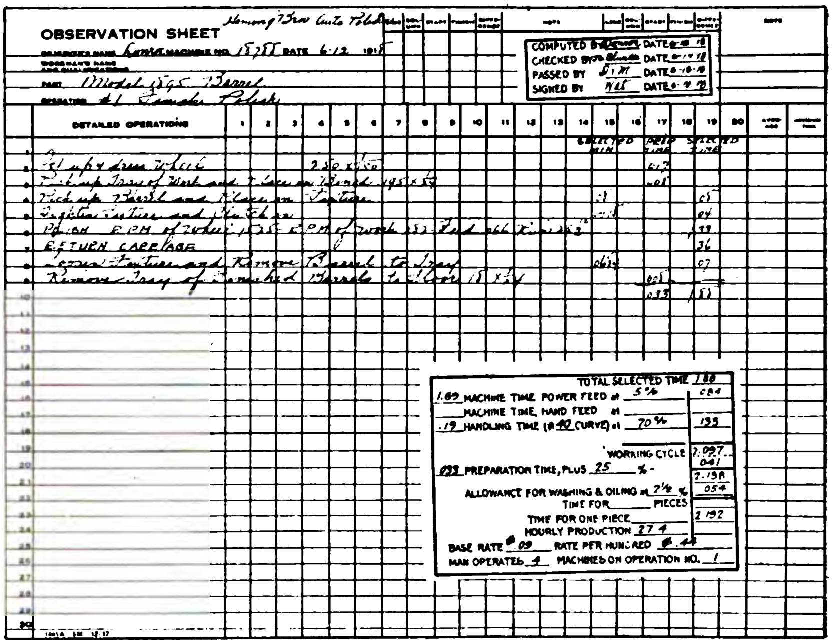
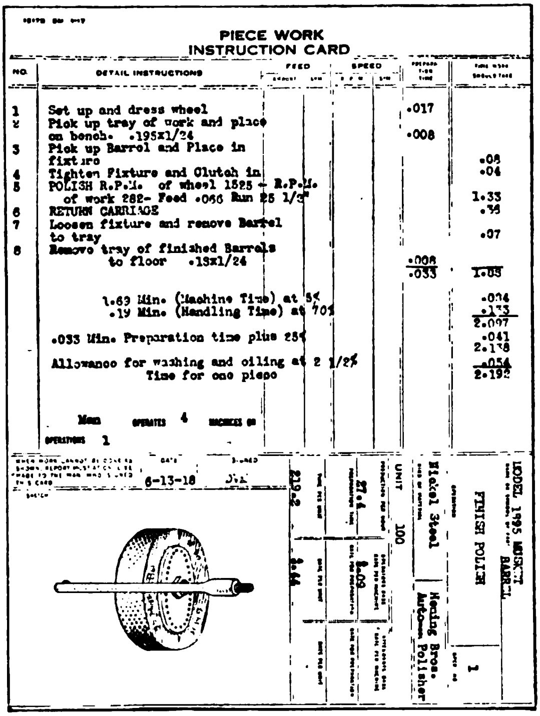


FIG. 9.—SUMMARY OF TIME STUDY ON POLISHING RIFLE BARREL

for polishing the barrel of a military rifle in a Heming Bros. automatic polishing machine. For some reason the workman appeared to be unable to accomplish the work in the time set by the study. As the taking of the study and the setting of the rates therefrom followed the procedure described in Chapter II, it was necessary to ascertain the reason for the workman's failure to complete his task in the time allowed.

Referring to Fig. 9 it will be noted that of the 1.88 minutes required for the completion of the cycle of element operations, 1.69 minutes are consumed by machine operations, and 0.19 minute in handling the work into and out of the machine. On the machine time a flat allowance of 5 per cent. is made and on the handling time, in establishing the rate, a percentage is

allowed which depends upon the proportion of the cycle time represented by the handling time of all the machines tended by the workman. The data shows that the operator runs four machines, and the assumption is made that on the same operation the handling time of each machine must be the same, or 0.76 minute. The cycle time being 1.88 minutes, the ratio of the total handling time to that of the cycle is 41 per cent. The allowance percentage for handling time in an operation involving proportional handling time of 41 per cent., the handling time for one machine being 0.19 minute, is 70 per cent. (see "Curves of Delay Allowances," Fig. 4). The allowances for the preparation of the machine, oiling and washing up, are arrived at as explained in Chapter II.



PIECE WORK INSTRUCTION CARD

NO.	DETAIL INSTRUCTIONS	PREPARATION TIME	TIME WORK
1	Set up and dress wheel	.017	
2	Pick up tray of work and place on bench. .195x1/24	.008	
3	Pick up Barrel and Place in fixture		.08
4	Tighten Fixture and Clutch in		.04
5	POLISH R.P.M. of wheel 1525 - R.P.M. of work 282- Feed .066 Run 25 1/3"		1.33
6	RETURN CARRIAGE		.36
7	Loosen fixture and remove Barrel to tray		.07
8	Remove tray of finished Barrels to floor .13x1/24	.008	
		.033	1.88
	1.69 Min. (Machine Time) at 5%		.084
	.19 Min. (Handling Time) at 70%		.133
			2.097
	.033 Min. Preparation time plus 25%		.041
			2.138
	Allowance for washing and oiling at 2 1/2%		.054
	Time for one piece		2.192

Man operates 4 machines on operations 1

6-13-18

219.2 27.4 UNIT 100 Nickel Steel FINISH POLISH MODEL 1895 MUSKET BARREL 1.64 3.09 Heming Bros. Art Polisher 1

FIG. 10.—INSTRUCTION CARD FOR POLISHING RIFLE BARREL

The time-study summary, Fig. 9, also shows that the machine operation naturally divides itself into four parts: the setting of the work in the machine, the polishing operation, the return of the machine to its initial position, and the removal of the work from the machine. These distinct acts are listed on the observation sheet of the production study, Fig. 11, as items *A*, *B*, *C*, and *D*, respectively. The other items listed on the summary observation sheet of the time study, Fig. 9, are not part of the cycle proper, but are operations performed on a group of pieces or on the machine after the completion of a certain number of pieces, and are pro-rated to the individual piece.

In conducting the production study, the observer com-

menced by noting and recording on the observation sheet (Fig. 11) the elapsed time of the complete cycle, operations *A* to *D*, inclusive. He found, however, that it was possible to separate the machine operations from the handling operations, and, after the first four pieces were made, he followed this procedure, noting the handling time before the machine operations, the two machine operations and the handling time after the machine operations as three separate groups. Twelve pieces were then

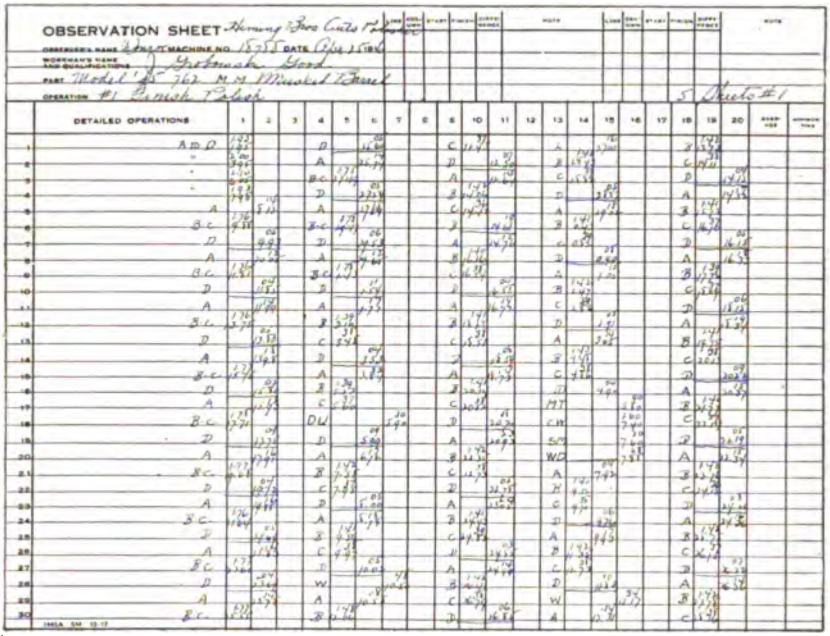


FIG. 11.—OBSERVATION SHEET OF PRODUCTION STUDY ON POLISHING RIFLE BARRELS

made under these conditions, when the desirability of still further division became apparent. The machine operations were accordingly separated and individual observations made of items *A*, *B*, *C*, and *D*.

The observer took differences as he proceeded with the study, inserting the individual times in the upper part of the spaces opposite the various items (see Fig. 11). The handling time is separated from the machine time by recording it in a different column on the observation sheet. While this is not absolutely necessary, it makes the analysis of the study somewhat easier than it would otherwise be and enables the observer quickly

to notice discrepancies in the performance of different parts of the job.

On line 18, column 4 of the observation sheet there is noted an interruption to the smooth progress of the work, symbolized by the letters *DU*. The significance of this observation is that there was an unavoidable delay, beginning at the completion of operation *C* (5.60 min.) and terminating 0.30 minute later (5.90 min.), after which operation *D* was performed in its regular order. The duration of this delay was entered in a different column from those employed for recording the machine and handling times. Similarly, in column 4, lines 17 to 20, other interruptions were recorded, designated by the symbols *MT*, *WC*, *MS*, and *WD*. This delay, totaling to 2.88 minutes, was occasioned by machine trouble which necessitated changing the wheel, starting the machine after the insertion of the fresh wheel and then dressing the wheel.

The recording of the observations of the complete production study required five observation sheets, only the first one of which is reproduced in Fig. 11, but the observations of the complete study, together with the individual times of the various operations and interruptions, are reproduced in Table A, where the various observations are designated by the following symbols:

Useful Operations.—*A*, handling of work before polishing; *B*, actual polishing in the machine; *C*, returning the machine carriage to its initial position; *D*, handling of work after the polishing operation.

Delays.—*DU*, unavoidable delay; *MT*, machine trouble; *WC*, changing wheel; *MS*, starting machine; *WD*, dressing wheel; *WM*, moving work.

TABLE A. THE PRODUCTION STUDY IN DETAIL

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay	Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
1	*A–D*	1.95	1.95	....	....	11	*A*	11.99	....	0.14	....
2	*A–D*	3.95	2.00	....	....	12	*B–C*	13.75	1.76	....	....
3	*A–D*	6.05	2 10	....	....	13	*D*	13.80	....	0.05	....
4	*A–D*	7.98	1.93	....	....	14	*A*	13.98	....	0.18	....
5	*A*	8.12	....	0.14	....	15	*B–C*	15.75	1.77	....	....
6	*B–C*	9.88	1.76	....	....	16	*D*	15.80	....	0.05	....
7	*D*	9.93	....	0.05	....	17	*A*	15.93	....	0.13	....
8	*A*	10.05	....	0.12	....	18	*B–C*	17.71	1.78	....	....
9	*B–C*	11.81	1.76	....	....	19	*D*	17.75	....	0.04	....
10	*D*	11.85	....	0.04	....	20	*A*	17.91	....	0.16	....

* The stop watch is graduated only for a total reading of 30 min., and it resets itself to zero at the end of the 30-min. period. Consequently, 30 min. must be added to the actual reading of the watch at the points noted (*) before subtracting to obtain the individual time.

† The observer for some reason not now apparent reset his watch to zero at this point.

TABLE A. THE PRODUCTION STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
21	*B–C*	19.68	1.77	....	....
22	*D*	19.72	....	0.04	....
23	*A*	19.88	....	0.16	....
24	*B–C*	21.64	1.76	....	....
25	*D*	21.69	....	0.05	....
26	*A*	21.83	....	0.14	....
27	*B–C*	23.60	1.77	....	....
28	*D*	23.64	....	0.04	....
29	*A*	23.78	....	0.14	....
30	*B–C*	25.55	1.77	....	....
31	*D*	25.60	....	0.05	....
32	*A*	25.74	....	0.14	....
33	*B–C*	27.49	1.75	....	....
34	*D*	27.54	....	0.05	....
35	*A*	27.69	....	0.15	....
36	*B–C*	29.47	1.78	....	....
37	*D*	29.53	....	0.06	....
38	*A*	29.65	....	0.12	....
39	*B–C**	1.43	1.78	....	....
40	*D*	1.54	....	0.11	....
41	*A*	1.71	....	0.17	....
42	*B*	3.10	1.39	....	....
43	*C*	3.48	0.38	....	....
44	*D*	3.52	....	0.04	....
45	*A*	3.84	....	0.32	....
46	*B*	5.23	1.39	....	....
47	*C*	5.60	0.37	....	....
48	*DU*	5.90	....	....	0.30
49	*D*	5.99	....	0.09	....
50	*A*	6.16	....	0.17	....
51	*B*	7.58	1.42	....	....
52	*C*	7.95	0.37	....	....
53	*D*	8.00	....	0.05	....
54	*A*	8.18	....	0.18	....
55	*B*	9.59	1.41	....	....
56	*C*	9.97	0.38	....	....
57	*D*	10.02	....	0.05	....
58	*WM*	10.50	....	....	0.48
59	*A*	10.58	....	0.08	....
60	*B*	12.06	1.48	....	....
61	*C*	12.43	0.37	....	....
62	*D*	12.50	....	0.07	....
63	*A*	12.64	....	0.14	....
64	*B*	14.06	1.42	....	....
65	*C*	14.42	0.36	....	....
66	*D*	14.61	....	0.19	....
67	*A*	14.76	....	0.15	....
68	*B*	16.16	1.40	....	....
69	*C*	16.54	0.38	....	....
70	*D*	16.58	....	0.04	....
71	*A*	16.72	....	0.14	....
72	*B*	18.13	1.41	....	....
73	*C*	18.51	0.38	....	....
74	*D*	18.59	....	0.08	....
75	*A*	18.73	....	0.14	....
76	*B*	20.14	1.41	....	....
77	*C*	20.52	0.38	....	....
78	*D*	20.70	....	0.18	....
79	*A*	20.93	....	0.23	....
80	*B*	22.35	1.42	....	....
81	*C*	22.73	0.38	....	....
82	*D*	22.78	....	0.05	....
83	*A*	23.02	....	0.24	....
84	*B*	24.43	1.41	....	....
85	*C*	24.82	0.39	....	....
86	*D*	24.85	....	0.03	....
87	*A*	24.99	....	0.14	....
88	*B*	26.41	1.42	....	....
89	*C*	26.79	0.38	....	....
90	*D*	26.85	....	0.06	....
91	*A*	27.01	....	0.16	....
92	*B*	28.43	1.42	....	....
93	*C*	28.82	0.39	....	....
94	*D*	28.87	....	0.05	....
95	*A*	29.02	....	0.15	....
96	*B**	0.43	1.41	....	....
97	*C*	0.82	0.39	....	....
98	*D*	0.90	....	0.08	....
99	*A*	1.05	....	0.15	....
100	*B*	2.47	1.42	....	....
101	*C*	2.86	0.39	....	....
102	*D*	2.91	....	0.05	....
103	*A*	3.05	....	0.14	....
104	*B*	4.48	1.43	....	....
105	*C*	4.86	0.38	....	....
106	*D*	4.90	....	0.04	....
107	*M T*	5.80	....	....	0.90
108	*W C*	7.40	....	....	1.60
109	*M S*	7.60	....	....	0.20
110	*W D*	7.88	....	....	0.28
111	*A*	7.92	....	0.04	....
112	*B*	9.32	1.40	....	....
113	*C*	9.70	0.38	....	....
114	*D*	9.76	....	0.06	....
115	*A*	9.93	....	0.17	....
116	*B*	11.35	1.42	....	....
117	*C*	11.73	0.38	....	....
118	*D*	11.83	....	0.10	....
119	*W M*	12.17	....	....	0.34
120	*A*	12.31	....	0.14	....
121	*B*	13.73	1.42	....	....
122	*C*	14.11	0.38	....	....
123	*D*	14.15	....	0.04	....
124	*A*	14.32	....	0.17	....
125	*B*	15.73	1.41	....	....
126	*C*	16.10	0.37	....	....
127	*D*	16.15	....	0.05	....
128	*A*	16.33	....	0.18	....
129	*B*	17.72	1.39	....	....
130	*C*	18.09	0.37	....	....
131	*D*	18.15	....	0.06	....
132	*A*	18.34	....	0.19	....
133	*B*	19.75	1.41	....	....
134	*C*	20.13	0.38	....	....
135	*D*	20.22	....	0.09	....
136	*A*	20.37	....	0.15	....
137	*B*	21.77	1.40	....	....
138	*C*	22.14	0.37	....	....

TABLE A. THE PRODUCTION STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
139	*D*	22.19	....	0.05	....
140	*A*	22.34	....	0.15	....
141	*B*	23.76	1.42	....	....
142	*C*	24.12	0.36	....	....
143	*D*	24.20	....	0.08	....
144	*A*	24.36	....	0.16	....
145	*B*	25.78	1.42	....	....
146	*C*	26.15	0.37	....	....
147	*D*	26.22	....	0.07	....
148	*A*	26.36	....	0.14	....
149	*B*	27.78	1.42	....	....
150	*C*	28.16	0.38	....	....
151	*D*	28.24	....	0.08	....
152	*A*	28.37	....	0.13	....
153	*B*	29.80	1.43	....	....
154	*C**	0.17	0.37	....	....
155	*D*	0.23	....	0.06	....
156	*A*	0.41	....	0.18	....
157	*B*	1.83	1.42	....	....
158	*C*	2.20	0.37	....	....
159	*D*	2.30	....	0.10	....
160	*A*	2.47	....	0.17	....
161	*B*	3.90	1.43	....	....
162	*C*	4.27	0.37	....	....
163	*D*	4.32	....	0.05	....
164	*A*	4.47	....	0.15	....
165	*B*	5.88	1.41	....	....
166	*C*	6.25	0.37	....	....
167	*D*	6.30	....	0.05	....
168	*A*	6.44	....	0.14	....
169	*B*	7.84	1.40	....	....
170	*C*	8.21	0.37	....	....
171	*D*	8.25	....	0.04	....
172	*A*	8.40	....	0.15	....
173	*B*	9.79	1.39	....	....
174	*C*	10.18	0.39	....	....
175	*D*	10.23	....	0.05	....
176	*A*	10.37	....	0.14	....
177	*B*	11.76	1.39	....	....
178	*C*	12.14	0.38	....	....
179	*D*	12.20	....	0.06	....
180	*A*	12.35	....	0.15	....
181	*B*	13.75	1.40	....	....
182	*C*	14.12	0.37	....	....
183	*D*	14.36	....	0.24	....
184	*W M*	14.78	....	....	0.42
185	*A*	14.95	....	0.17	....
186	*B*	16.33	1.38	....	....
187	*C*	16.71	0.38	....	....
188	*D*	16.88	....	0.17	....
189	*A*	17.07	....	0.19	....
190	*B*	18.45	1.38	....	....
191	*C*	18.83	0.38	....	....
192	*D*	18.91	....	0.08	....
193	*A*	19.06	....	0.15	....
194	*B*	20.45	1.39	....	....
195	*C*	20.82	0.37	....	....
196	*D*	20.88	....	0.06	....
197	*A*	21.01	....	0.13	....
198	*B*	22.40	1.39	....	....
199	*C*	22.78	0.38	....	....
200	*D*	22.83	....	0.05	....
201	*A*	22.94	....	0.11	....
202	*B*	24.33	1.39	....	....
203	*C*	24.71	0.38	....	....
204	*D*	24.75	....	0.04	....
205	*A*	24.88	....	0.13	....
206	*B*	26.26	1.38	....	....
207	*C*	26.63	0.37	....	....
208	D†	26.69	....	0.06	....
209	*A*	0.22	....	0.22	....
210	*B*	1.68	1.46	....	....
211	*C*	2.07	0.39	....	....
212	*D*	2.23	....	0.16	....
213	*A*	2.38	....	0.15	....
214	*B*	3.85	1.47	....	....
215	*C*	4.25	0.40	....	....
216	*D*	4.35	....	0.10	....
217	*A*	4.53	....	0.18	....
218	*B*	6.02	1.49	....	....
219	*C*	6.42	0.40	....	....
220	*D*	6.55	....	0.13	....
221	*A*	6.70	....	0.15	....
222	*B*	8.19	1.49	....	....
223	*C*	8.59	0.40	....	....
224	*D*	8.67	....	0.08	....
225	*A*	8.83	....	0.16	....
226	*B*	10.33	1.50	....	....
227	*C*	10.75	0.42	....	....
228	*D*	10.84	....	0.09	....
229	*A*	11.00	....	0.16	....
230	*B*	12.52	1.52	....	....
231	*C*	12.93	0.41	....	....
232	*D*	13.02	....	0.09	....
233	*A*	13.20	....	0.18	....
234	*B*	14.72	1.52	....	....
235	*C*	15.13	0.41	....	....
236	*D*	15.23	....	0.10	....
237	*A*	15.38	....	0.15	....
238	*B*	16.91	1.53	....	....
239	*C*	17.33	0.42	....	....
240	*D*	17.42	....	0.09	....
241	*A*	17.59	....	0.17	....
242	*B*	19.16	1.57	....	....
243	*C*	19.56	0.40	....	....
244	*D*	19.65	....	0.09	....
245	*A*	19.83	....	0.18	....
246	*B*	21.40	1.57	....	....
247	*C*	21.82	0.42	....	....
248	*D*	21.89	....	0.07	....
249	*A*	22.04	....	0.15	....
250	*B*	23.65	1.61	....	....
251	*C*	24.07	0.42	....	....
252	*D*	24.18	....	0.11	....
253	*W M**	30.00	....	....	5.82
254	*M S*	0.40	....	....	0.40
255	*A*	0.52	....	0.12	....
256	*B*	2.17	1.65	....	....

TABLE A. THE PRODUCTION STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
257	*C*	2.60	0.43	....	....
258	*D*	2.68	....	0.08	....
259	*A*	2.85	....	0.17	....
260	*B*	4.53	1.68	....	....
261	*C*	4.97	0.44	....	....
262	*D*	5.05	....	0.08	....
263	*A*	5.21	....	0.16	....
264	*B*	6.92	1.71	....	....
265	*C*	7.36	0.44	....	....
266	*D*	7.53	....	0.17	....
267	*A*	7.71	....	0.18	....
268	*B*	9.43	1.72	....	....
269	*C*	9.86	0.43	....	....
270	*D*	9.94	....	0.08	....
271	*A*	10.11	....	0.17	....
272	*B*	11.82	1.71	....	....
273	*C*	12.25	0.43	....	....
274	*D*	12.40	....	0.15	....
275	*A*	12.56	....	0.16	....
276	*B*	14.23	1.67	....	....
277	*C*	14.65	0.42	....	....
278	*D*	14.74	....	0.09	....
279	*A*	14.91	....	0.17	....
280	*B*	16.64	1.73	....	....
281	*C*	17.06	0.42	....	....
282	*D*	17.18	....	0.12	....
283	*A*	17.33	....	0.15	....
284	*B*	19.08	1.75	....	....
285	*C*	19.51	0.43	....	....
286	*D*	19.59	....	0.08	....
287	*A*	19.82	....	0.23	....
288	*B*	21.57	1.75	....	....
289	*C*	22.00	0.43	....	....
290	*D*	22.08	....	0.08	....
291	*A*	22.23	....	0.15	....
292	*B*	23.99	1.76	....	....
293	*C*	24.41	0.42	....	....
294	*D*	24.52	....	0.11	....
295	*A*	24.77	....	0.25	....
296	*B*	26.56	1.79	....	....
297	*C*	26.98	0.42	....	....
298	*D*	27.08	....	0.10	....
299	*A*	27.28	....	0.20	....
300	*B*	29.06	1.78	....	....
301	*C*	29.49	0.43	....	....
302	*D*	29.58	....	0.09	....
303	*A*	29.76	....	0.18	....
304	B*	1.54	1.78	....	....
305	*C*	1.97	0.43	....	....
306	*D*	2.07	....	0.10	....
307	*A*	2.21	....	0.14	....
308	*B*	3.98	1.77	....	....
309	*C*	4.40	0.42	....	....
310	*D*	4.51	....	0.11	....
311	*A*	4.66	....	0.15	....
312	*B*	6.32	1.66	....	....
313	*C*	6.73	0.41	....	....
314	*D*	6.90	....	0.17	....
315	*A*	7.08	....	0.18	....
316	*B*	8.76	1.68	....	....
317	*C*	9.15	0.39	....	....
318	*D*	9.30	....	0.15	....
319	*A*	9.45	....	0.15	....
320	*B*	11.09	1.64	....	....
321	*C*	11.52	0.43	....	....
322	*D*	11.59	....	0.07	....
323	*A*	11.73	....	0.14	....
324	*B*	13.37	1.64	....	....
325	*C*	13.80	0.43	....	....
326	*D*	13.89	....	0.09	....
327	*A*	14.05	....	0.16	....
328	*B*	15.69	1.64	....	....
329	*C*	16.11	0.42	....	....
330	*D*	16.20	....	0.09	....
331	*A*	16.35	....	0.15	....
332	*B*	17.98	1.63	....	....
333	*C*	18.40	0.42	....	....
334	*D*	18.48	....	0.08	....
335	*A*	18.62	....	0.14	....
336	*B*	20.28	1.66	....	....
337	*C*	20.70	0.42	....	....
338	*D*	20.78	....	0.08	....
339	*A*	20.93	....	0.15	....
340	*B*	22.60	1.67	....	....
341	*C*	23.02	0.42	....	....
342	*D*	23.11	....	0.09	....
343	*A*	23.29	....	0.18	....
344	*B*	24.93	1.64	....	....
345	*C*	25.36	0.43	....	....
346	*D*	25.43	....	0.07	....
347	*A*	25.63	....	0.20	....
348	*B*	27.28	1.65	....	....
349	*C*	27.69	0.41	....	....
350	*D*	27.97	....	0.28	....
351	*A*	28.14	....	0.17	....
352	*B**	29.79	1.65	....	....
353	*C*	0.21	0.42	....	....
354	*D*	0.29	....	0.08	....
355	*A*	0.44	....	0.15	....
356	*B*	2.09	1.65	....	....
357	*C*	2.50	0.41	....	....
358	*D*	2.60	....	0.10	....
359	*A*	2.76	....	0.16	....
360	*B*	4.45	1.69	....	....
361	*C*	4.88	0.43	....	....
362	*D*	4.96	....	0.08	....
363	*A*	5.14	....	0.18	....
364	*B*	6.82	1.68	....	....
365	*C*	7.25	0.43	....	....
366	*D*	7.35	....	0.10	....
367	*A*	7.50	....	0.15	....
368	*B*	9.21	1.71	....	....
369	*C*	9.63	0.42	....	....
370	*D*	9.73	....	0.10	....
371	*A*	9.92	....	0.19	....
372	*B*	11.61	1.69	....	....
373	*C*	12.05	0.44	....	....
374	*D*	12.15	....	0.10	....

TABLE A. THE PRODUCTON STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
375	*A*	12.33	....	0.18	....
376	*B*	14.08	1.75	....	....
377	*C*	14.52	0.44	....	....
378	*D*	14.59	....	0.07	....
379	*A*	14.78	....	0.19	....
380	*B*	16.52	1.74	....	....
381	*C*	16.94	0.42	....	....
382	*D*	17.15	....	0.21	....
383	*A*	17.30	....	0.15	....
384	*B*	18.98	1.68	....	....
385	*C*	19.41	0.43	....	....
386	*D*	19.47	....	0.06	....
387	*A*	19.63	....	0.16	....
388	*B*	21.36	1.73	....	....
389	*C*	21.78	0.42	....	....
390	*D*	21.85	....	0.07	....
391	*A*	21.98	....	0.13	....
392	*B*	23.69	1.71	....	....
393	*C*	24.12	0.43	....	....
394	*D*	24.24	....	0.12	....
395	*A*	24.42	....	0.18	....
396	*B*	26.12	1.70	....	....
397	*C*	26.56	0.44	....	....
398	*D*	26.63	....	0.07	....
399	*A*	26.86	....	0.23	....
400	*B*	28.60	1.74	....	....
401	*C*	29.04	0.44	....	....
402	*D*	29.13	....	0.09	....
403	*A**	29.31	....	0.18	....
404	*B*	1.06	1.75	....	....
405	*C*	1.48	0.42	....	....
406	*D*	1.57	....	0.09	....
407	*A*	1.73	....	0.16	....
408	*B*	3.47	1.74	....	....
409	*C*	3.90	0.43	....	....
410	*D*	4.02	....	0.12	....
411	*A*	4.17	....	0.15	....
412	*B*	5.93	1.76	....	....
413	*C*	6.36	0.43	....	....
414	*D*	6.48	....	0.12	....
415	*A*	6.67	....	0.19	....
416	*B*	8.44	1.77	....	....
417	*C*	8.88	0.44	....	....
418	*D*	9.00	....	0.12	....
419	*A*	9.18	....	0.18	....
420	*B*	10.93	1.75	....	....
421	*C*	11.37	0.44	....	....
422	*D*	11.44	....	0.07	....
423	*A*	11.60	....	0.16	....
424	*B*	13.37	1.77	....	....
425	*C*	13.81	0.44	....	....
426	*D*	13.90	....	0.09	....
427	*A*	14.06	....	0.16	....
428	*B*	15.86	1.80	....	....
429	*C*	16.29	0.43	....	....
430	*D*	16.37	....	0.08	....
431	*A*	16.56	....	0.19	....
432	*B*	18.38	1.82	....	....
433	*C*	18.81	0.43	....	....
434	*D*	18.98	....	0.17	....
435	*M T*	19.60	....	....	0.62
436	*W C*	21 90	....	....	2.30
437	*M S*	22.45	....	....	0.55
438	*W D*	23.65	....	....	1.20
439	*A*	23.82	....	0.17	....
440	*B*	25.33	1.51	....	....
441	*C*	25.74	0.41	....	....
442	*D*	25.79	....	0.05	....
443	*A*	25.92	....	0.13	....
444	*B*	27.49	1.57	....	....
445	*C*	27.93	0.44	....	....
446	*D*	28.11	....	0.18	....
447	*A*	28.32	....	0.21	....
448	*B**	29.92	1.60	....	....
449	*C*	0.34	0.42	....	....
450	*D*	0.45	....	0.11	....
451	*A*	0.64	....	0.19	....
452	*B*	2.26	1.62	....	....
453	*C*	2.68	0.42	....	....
454	*D*	2.78	....	0.10	....
455	Adjust Mach.	3.24	....	....	0.46
456	*A*	3.38	....	0.14	....
457	*B*	5.01	1.63	....	....
458	*C*	5.43	0.42	....	....
459	*D*	5.54	....	0.11	..
460	Insp. Work	5.70	....	....	0.16
461	Adjust Mach.	5.85	....	....	0.15
462	*A*	6.09	....	0.24	....
463	*B*	7.78	1.69	....	....
464	*C*	8.22	0.44	....	....
465	*D*	8.31	....	0.09	....
466	*W M*	8.69	....	....	0.38
467	*A*	8.82	....	0.13	....
468	*B*	10.53	1.71	....	....
469	*C*	10.96	0.43	....	....
470	*D*	11.07	....	0.11	....
471	*A*	11.21	....	0.14	....
472	*B*	12.98	1.77	....	....
473	*C*	13.43	0.45	....	....
474	*D*	13.50	....	0.07	....
475	*A*	13.65	....	0.15	....
476	*B*	15.45	1.80	....	....
477	*C*	15.90	0.45	....	....
478	*D*	15.97	....	0.07	....
479	*A*	16.11	....	0.14	....
480	*B*	17.88	1.77	....	....
481	*C*	18.32	0.44	....	....
482	*D*	18.42	....	0.10	....
483	*A*	18.59	....	0.17	....
484	*B*	20.37	1.78	....	....
483	*C*	20.80	0.43	....	....
486	*D*	20.87	....	0.07	....
487	*A*	21.04	....	0.17	....
488	*B*	22.80	1.76	....	....
489	*C*	23.23	0.43	....	....

TABLE A. THE PRODUCTION STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min.		
			Machine	Handling	Delay
490	*D*	23.31	....	0.08	....
491	*A*	23.46	....	0.15	....
492	*B*	25.18	1.72	....	....
493	*C*	25.60	0.42	....	....
494	*D*	25.67	....	0.07	....
495	*M T*	25.94	....	....	0.27
496	*A*	26.07	....	0.13	....
497	*B*	27.43	1.36	....	....
498	*C*	27.80	0.37	....	....
499	*D*	27.90	....	0.10	....
500	*A*	28.15	....	0.15	....
501	*B*	29.51	1.36	....	....
502	*C*	29.89	0.38	....	....
503	*D*	29.97	....	0.08	....
504	*A**	0.10	....	0.13	....
505	*B*	1.46	1.36	....	....
506	*C*	1.83	0.37	....	....
507	*D*	1.90	....	0.07	....
508	*A*	2.10	....	0.20	....
509	*B*	3.45	1.35	....	....
510	*C*	3.82	0.37	....	....
511	*D*	3.90	....	0.08	....
512	*A*	4.06	....	0.16	....
513	*B*	5.40	1.34	....	....
514	*C*	5.78	0.38	....	....
515	*D*	5.85	....	0.07	....
516	*A*	5.98	....	0.13	....
517	*B*	7.34	1.36	....	....
518	*C*	7.69	0.35	....	....
519	*D*	7.78	....	0.09	....
520	*A*	7.98	....	0.20	....
521	*B*	9.32	1.34	....	....
522	*C*	9.69	0.37	....	....
523	*D*	9.77	....	0.08	....
524	*A*	9.91	....	0.14	....
525	*B*	11.26	1.35	....	....
526	*C*	11.62	0.36	....	....
527	*D*	11.71	....	0.09	....
528	*A*	11.90	....	0.19	....
529	*B*	13.25	1.35	....	....
530	*C*	13.61	0.36	....	....
531	*D*	13.70	....	0.09	....
532	*A*	13.86	....	0.16	....
533	*B*	15.21	1.35	....	....
534	*C*	15.57	0.36	....	....
535	*D*	15.65	....	0.08	....
536	*A*	15.80	....	0.15	....
537	*B*	17.14	1.34	....	....
538	*C*	17.51	0.37	....	....
539	*D*	17.55	....	0.04	....
540	*A*	17.69	....	0.14	....
541	*B*	19.03	1.34	....	....
542	*C*	19.39	0.36	....	....
543	*D*	19.58	....	0.19	....
544	*A*	19.74	....	0.16	....
545	*B*	21.08	1.34	....	....
546	*C*	21.44	0.36	....	....
547	*D*	21.66	....	0.22	....
548	*A*	21.80	....	0.14	....
549	*B*	23.16	1.36	....	....
550	*C*	23.51	0.35	....	....
551	*D*	23.59	....	0.08	....
552	*A*	23.76	....	0.17	....
553	*B*	25.09	1.33	....	....
554	*C*	25.44	0.35	....	....
555	*D*	25.79	....	0.35	....
556	*A*	25.94	....	0.15	....
557	*B*	27.28	1.34	....	....
558	*C*	27.63	0.35	....	....
559	*D*	27.71	....	0.08	....
560	*A*	27.87	....	0.16	....
561	*B*	29.21	1.34	....	....
562	*C*	29.57	0.36	....	....
563	*D*	29.67	....	0.10	....
564	*A*	29.82	....	0.15	....
565	*B**	1.16	1.34	....	....
566	*C*	1.51	0.35	....	....
567	*D*	1.62	....	0.11	....
568	*A*	1.78	....	0.16	....
569	*B*	3.12	1.34	....	....
570	*C*	3.47	0.35	....	....
571	*D*	3.54	....	0.07	....
572	*A*	3.69	....	0.15	....
573	*B*	5.05	1.36	....	....
574	*C*	5.40	0.35	....	....
575	*D*	5.47	....	0.07	....
576	*A*	5.60	....	0.13	....
577	*B*	6.94	1.34	....	....
578	*C*	7.30	0.36	....	....
579	*D*	7.37	....	0.07	....
580	*A*	7.50	....	0.13	....
581	*B*	8.83	1.33	....	....
582	*C*	9.20	0.37	....	....
583	*D*	9.29	....	0.09	....
584	*A*	9.42	....	0.13	....
585	*B*	10.76	1.34	....	....
586	*C*	11.12	0.36	....	....
587	*D*	11.18	....	0.06	....
588	*A*	11.32	....	0.14	....
589	*B*	12.65	1.33	....	....
590	*C*	13.01	0.36	....	....
591	*D*	13.09	....	0.08	....
592	*A*	13.25	....	0.16	....
593	*B*	14.60	1.35	....	....
594	*C*	14.95	0.35	....	....
595	*D*	15.05	....	0.10	....
596	*A*	15.21	....	0.16	....
597	*B*	16.53	1.32	....	....
598	*C*	16.89	0.36	....	....
599	*D*	16.99	....	0.10	....
600	*A*	17.17	....	0.18	....
601	*B*	18.49	1.32	....	....
602	*C*	18.86	0.37	....	....
603	*D*	18.93	....	0.07	....
604	*A*	19.07	....	0.14	....
605	*B*	20.40	1.33	....	....
606	*C*	20.76	0.36	....	....
607	*D*	20.84	....	0.08	....

TABLE A. THE PRODUCTION STUDY IN DETAIL (*Continued*)

Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay	Observation, No.	Operation	Continuous Time, Min.	Individual Time, Min. Machine	Handling	Delay
608	*A*	20.99	....	0.15	....	634	*C*	4.20	0.35	....	....
609	*B*	22.33	1.34	....	....	635	*D*	4.30	....	0.10	....
610	*C*	22.68	0.35	....	....	636	*A*	4.42	....	0.12	....
611	*D*	22.77	....	0.09	....	637	*B*	5.76	1.34	....	....
612	*A*	22.90	....	0.13	....	638	*C*	6.11	0.35	....	....
613	*B*	24.23	1.33	....	....	639	*D*	6.17	....	0.06	....
614	*C*	24.60	0.37	....	....	640	*A*	6.32	....	0.15	....
615	*D*	24.67	....	0.07	....	641	*B*	7.64	1.32	....	....
616	*A*	24.82	....	0.15	....	642	*C*	8.00	0.36	....	....
617	*B*	26.16	1.34	....	....	643	*D*	8.08	....	0.08	....
618	*C*	26.51	0.35	....	....	644	*A*	8.22	....	0.14	....
619	*D*	26.57	....	0.06	....	645	*B*	9.54	1.32	....	....
620	*A*	26.71	....	0.14	....	646	*C*	9.90	0.36	....	....
621	*B*	28.05	1.34	....	....	647	*D*	9.98	....	0.08	....
622	*C*	28.41	0.36	....	....	648	*A*	10.11	....	0.13	....
623	*D*	28.48	....	0.07	....	649	*B*	11.43	1.32	....	....
624	*A*	28.63	....	0.15	....	650	*C*	11.79	0.36	....	....
625	*B*	29.97	1.34	....	....	651	*D*	11.87	....	0.08	....
626	*C**	0.33	0.36	....	....	652	*A*	12.02	....	0.15	....
627	*D*	0.44	....	0.11	....	653	*B*	13.34	1.32	....	....
628	*A*	0.63	....	0.19	....	654	*C*	13.69	0.35	....	....
629	*B*	1.96	1.33	....	....	655	*D*	13.80	....	0.11	....
630	*C*	2.32	0.36	....	....	656	*A*	13.95	....	0.15	....
631	*D*	2.39	....	0.07	....	657	*B*	15.28	1.33	....	....
632	*A*	2.52	....	0.13	....	658	*C*	15.64	0.36	....	....
633	*B*	3.85	1.33	....	....	659	*D*	16.04	....	0.40	....

A careful study of Table A will reveal how important it is to subdivide the operations as far as possible, and also how important it is to take differences as the study proceeds. Take, for example, operation *B*, that of polishing. During the early stages of the study, the time consumed for this one operation ranged from 1.39 to 1.48 minutes. Commencing with observation No. 210 (Table A), the time consumed by the operation commenced to lengthen progressively, reaching a maximum of 1.82 minutes at observation No. 432. This poor rate remained approximately the same until, at observation No. 494, the observer called the attention of the room foreman to the trouble, suggesting that a belt dressing be applied to correct an apparent slippage of the driving belt. This was done—the resultant delay noted by the symbol *MT*, observation No. 495—and upon resuming work, the time for operation *B* dropped to 1.36 minutes (observation No. 497), and did not rise again beyond that during the balance of the study.

The production study is summarized, the individual times relating to the various operations totaled and entered on the summary sheet, Fig. 12, and, similarly, the sums of the individual times of the various classes of delays are entered.

The various totals are divided by the number of pieces made during the production study in order to make a comparison of the results with the original time study.

The most instructive figures in the production summary in the present case are those of the cycle times. Reference to the table will show that a total of 165 pieces were machined. Of

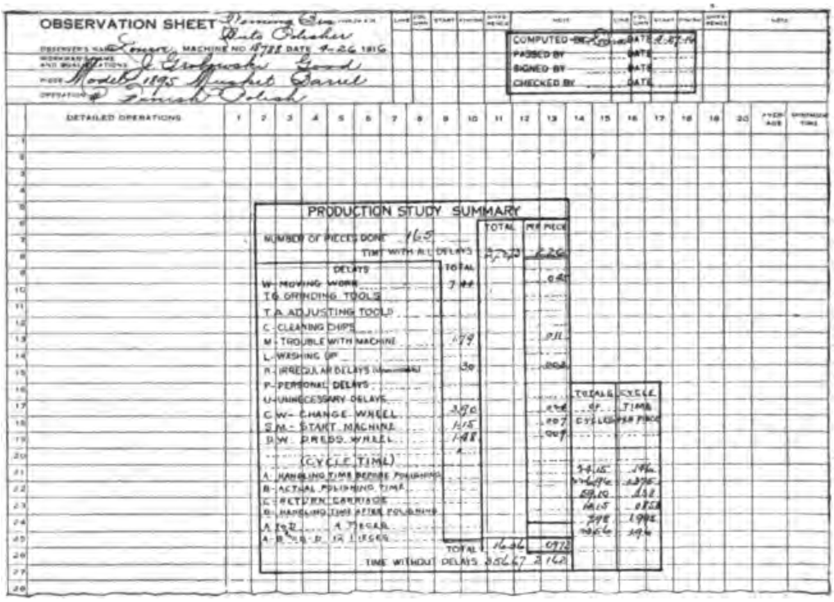


FIG. 12.—SUMMARY OF PRODUCTION STUDY ON POLISHING RIFLE BARREL

these, the handling time was determined separately after the first four pieces were machined, or on a total of 161 pieces. The machine operations were separated after the first 16 pieces were completed, or on 149 pieces. The totals of the handling time for the 161 pieces, for operations *A* and *D* respectively, were 25.77 min. and 14.15 min., and the average handling time per piece for these two operations was as follows: *A*—25.77 ÷ 161 = 0.159 min.; *D*—14.15 ÷ 161 = 0.091 min. Likewise the machine times for 149 pieces were: Operation *B*—total, 226.96 min.; average per piece, 1.523 min. Operation *C*—total, 59.10 min.; average per piece, 0.396 min.

The significance of these figures can be grasped if they are compared with the figures of the time-study summary, Fig. 9, and with the allowances for the two kinds of work. This is done in Table B.

An inspection of columns 5 and 6 of this table immediately reveals the fact that the trouble was due to the machine. In those operations which depended on the dexterity of the operator the production time was well within the allowed time. In fact, it closely approached the selected minimum time. On the other hand, in the machine operations, over which the operator had little or no control, the production time exceeded the allowed time

TABLE B—COMPARISON OF TIME-STUDY AND PRODUCTION-STUDY SUMMARIES

Time given is in minutes per piece

1	2	3	4	5	6
Operation	Time Study, Min.	Allowance, Per Cent.	Allowance, Min.	Total Time Allowed, Min.	Production Study, Min.
A...........	0.12	70	0.0840	0.204	0.159
B...........	1.33	5	0.0665	1.3965	1.523
C...........	0.36	5	0.0180	0.378	0.396
D..........	0.07	70	0.0490	0.119	0.091

by a large margin. As already pointed out, this was due to the slipping of the belt, which fault was recognized and corrected during the progress of the production study. It is quite conceivable, however, that in a great number of cases the trouble would not be so obvious, and an analysis and comparison such as is illustrated in Table B would be necessary to determine where the difficulty lay.

The items in the production study outside of the regular cycle of work operations can be analyzed in the same manner. These are listed in the production-study summary under the head of "Delays." Take, for instance, the item of moving work. The instruction card calls for the rifle barrels to be moved in lots of 24 and allows an average time per piece of 0.016 minute (see Items 2 and 8, Fig. 10), plus an allowance of 25 per cent. The total time allowed for the 165 pieces will then be:

Total selected time................................	165 x 0.016 =	2.64 min.
Allowance..	2.64 x 0.25 =	0.66 min.
Total time allowed..		3.30 min.

The production-study summary shows (Item *W*) that the operator consumed 7.44 minutes in moving the work, or 4.14 minutes more than necessary.

The instruction card calls for the setting up and dressing f the wheel for every 150 pieces, setting, per piece for this purpose, an average time of 0.017 minute plus the standard

25 per cent. time allowance. The allowed time and the actual time consumed work out as follows:

Total selected time	165 x 0.017	= 2.805 min.
Allowance	2.805 x 0.25	= 0.701 min.
Total time allowed		3.506 min.
Time actually consumed (Items *CW*, *SM*, *DW*)		6.530 min.
Excess of time consumed		3.024 min.

In addition there were two delays of 1.79 minutes, due to machine trouble and 0.30 minute to an unavoidable cause. The total time lost unnecessarily is then the sum of the four losses noted, or 9.254 minutes, which is well within the time saved on cycle operations *A* and *D* through bettering the set-time allowances (see Table B) for the handling operations. However, the time-study summary, Fig. 9, gives the minimum time per piece as 1.88 minutes and the allowed time, exclusive only of the time allotted for washing, as 2.138 minutes. The gross delay allowance per piece is then 13.7 per cent. [(2.138 — 1.88) ÷ 1.88], or 0.258 minute per piece. The estimated allowances for delays—there being 165 pieces—totals to 42.57 minutes, so the unnecessary delays exceeded the total delay allowances by 21.74 per cent., but, being confined to machine operations, this excess was possible of elimination.

From the foregoing, it is evident that a production study will promptly reveal such facts as whether the operator is deliberately wasting time, either by unnecessarily leaving his machine, by engaging in needless conversation with fellow-workers, or by other delinquencies. It will also reveal lack of skill—apparent in excessive handling time or frequent adjustment of machine or tools—as well as unnecessary delays in furnishing work to the operator. The production study investigated confirmed the correctness of the previous time study, for nearly all the operations, other than the machine operations, were conducted in close to minimum time; and the machine operations were also performed according to schedule as soon as the machine trouble had been rectified. The value of the production study cannot be overestimated. It is an important and necessary adjunct to time study.

CHAPTER IV

PRODUCTION-TIME STUDIES ON AUTOMATIC MACHINES

THE production-time study of automatic machinery differs from that of ordinary non-automatic in that in the latter the time required to perform the component parts of the complete operation is taken, while in the former the time lost by stoppages and delays to continuous operation of one kind or another is noted. For instance, the production of a drawing press with a magazine feed could be absolutely predetermined by multiplying the speed of the machine in revolutions per minute by the number of minutes that it is in operation per day, provided there were to be no stoppages of any kind. But it is impossible to operate presses, or any other machine, with an assurance that there will be no interruptions, for tools will become dull and require changing, the supply of material may fail, the operator will need a certain amount of time for his personal necessities which will involve stopping the machine, parts of the equipment may require adjustment; any one of a number of causes may occur to delay or stop the work.

It is the function of time study on automatic machines to ascertain what these delays are, what is the probable interval of their recurrence and the duration of each. From these data a factor can be determined that may be applied to the ideal capacity of the machine to give with reasonable accuracy the production that normally should be obtained. At the same time, information is acquired regarding delays that are unnecessary and provision can frequently be made for their elimination. Improvements in equipment that will minimize the unavoidable delays, such as are attendant to machine operation, may also be indicated by the study.

In short, time study of non-automatic machinery concerns itself only with useful, productive operations. Time study of automatic machines concerns itself not at all with productive time, except incidentally, but is vitally interested in the time expended in useless or inefficient operations. The first examines, in detail, the production of the individual piece. The second

looks after production in the mass and determines the time required to produce a quantity of pieces.

It is therefore evident that time study of automatic machinery must be carried out on a somewhat different basis than the operation-time studies that have previously been described. The studies should extend over a relatively long period of time, usually at least two days and often ten days. This is necessary in order that the observer may be sure, through the recurrence of delays of the same character, that he has made observations of every class of interruption likely to take place in the usual course of work. It is also necessary to ascertain the average rate of production of the particular equipment under study, for it is well known that the speed of lineshafts will vary from hour to hour and that the speed of the machine itself will vary independently of lineshaft variations, owing to belt slippage and other causes. The production study must be of sufficient duration to take into consideration all of these variations.

Studies of automatic machinery may be divided into two classes: (1) Where the individual pieces are produced so rapidly that there is an insufficient interval between them to record the time of production of each separate piece, and (2) where the interval between the individual pieces is sufficiently great to permit the production of each piece to be noted and recorded separately. In the latter case, the study partakes largely of the nature of the production study described in Chapter III, and the difficulties of analysis are no greater than those of the production study. In the first case, where the production is extremely rapid, it is necessary to take the average production and apportion all delays to this average production.

In taking studies of automatic or semi-automatic machinery, the observations and work incidental thereto arrange themselves into seven distinct but closely correlated divisions.

1. A preliminary study and analysis of the work and of all the influencing conditions, in order that the observer may obtain a clear conception of the work of the machine and the duties of its attendant. This study gives him a general knowledge of the operation as a whole and of all the factors that contribute to delay it, including the physical and mental condition of the operator.

2. Observation of the machine or group of machines and their attendants under working conditions for a considerable period of time. During this observation, which is the time study proper, note is made of the production, speed of the machine, time of interruptions and the duration of all delays,

together with notations of the cause of such delays. These observations should be started at the beginning of the day and should be continued until the observer is satisfied that the delays are repeating themselves. The production—that is, the quantity of pieces made by the machine—should be noted at regular intervals. Fifteen-minute intervals will usually be found satisfactory for most classes of work. The speed of the machine should be noted at least twice during each half-day, and more often if the conditions seem to make it advisable.

3. Observations of several groups of machines having the same general features and operating on the same type of work.

4. Summation of the various delays, the production time, etc., for the duration of the period under which the machines were under observation and the reduction of the data to a period basis of one day.

5. Study and analysis of the time records leading to the selection of a governing factor that runs through all studies, and by means of which they may be compared. As a result of this analysis, data are secured from which curves are plotted for each unavoidable or reasonable delay for which an allowance should be provided.

6. The selection from the delay curves or records of fair values for each of the delays for which allowance should be made.

7. The preparation of instruction cards on which the necessary delays are listed and allowances made for fatigue, washing, etc., for the guidance of the operator.

A description of a typical time study on automatic machines —the selected study, one conducted on a series of heading presses performing one of the operations in the manufacture of a brass small arms cartridge cases—will illustrate the procedure followed in collecting the necessary data, etc.

The production attained on the various machines was ascertained by reading the counter on the press at the beginning and at the end of the study and at fifteen-minute intervals during the study, recording the speeds on the production observation card (see Fig. 13) which records the data secured during an afternoon of the study on two of the automatic heading presses working on 0.44 caliber cartridge cases. The object of the counter readings at fifteen-minute intervals is that if an abnormal interruption occurs during the course of the study, the counter readings preceding and following the interruption can be noted and the study during the interval omitted. In this manner a relatively minor accident will

not spoil a study that had been going on for a considerable time. The minor delays, as they occur in any fifteen-minute period, are recorded in the column headed "Remarks," opposite the figure denoting the commencement of the period. Thus the delays occurring between seven and seven-fifteen are entered opposite "7.00"; those taking place between seven-

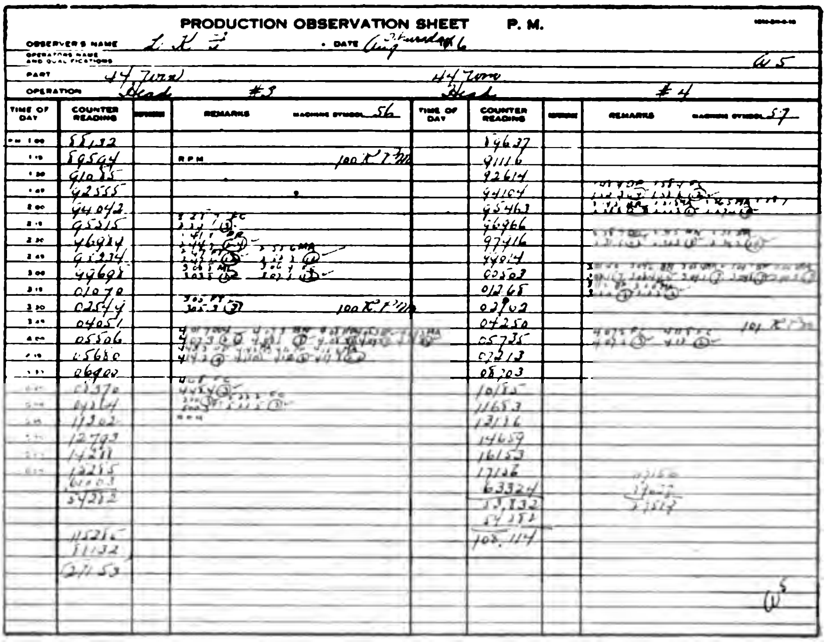


FIG. 13.—PRODUCTION-OBSERVATION SHEET ON AN AUTOMATIC HEADING PRESS

fifteen and seven-thirty, opposite "7.15." etc. The time at which the delay commenced and also when it ended are also recorded with the delay symbol and elapsed time.

The delay symbols employed to designate the kind of delay in the study under consideration are as follows: *MA*, adjust machine; *TC*, change ticket; *FT*, feed trouble; *FC*, feed clog in pipe; *DN*, new die; *BN*, new bunters; *PN*, new punch; *NO*, operator absent; *WN*, no work; *DP*, polish die; *BP*, polish bunter; *PP*, polish punch; *AW*, wait for adjuster; *AU*, unnecessary; *ML*, oil; *UW*, wash; *PS*, straighten punch; *AP*, personal; *PPDB*, polish punch, die, and bunter.

Referring to Fig. 13, the first entry in the "Remarks" column for machine No. 56 is "2.28.7 *FC*." This signifies that at

twenty-eight and seven-tenths minutes after two the feed pipe clogged. The notation, "2.29," directly under the time at which the delay occurred indicates that the trouble was rectified at that time, and the time lost by the interruption, three-tenths of a minute, is denoted by encircling the entry. During the next fifteen-minute period the workman stopped the machine to polish the punch—indicated by the entry, "2.41.8 *PP*"—and lost two and four-tenths minutes, resuming work at forty-four and two-tenths minutes past two. The amount of time lost is indicated in all cases by drawing a circle about the figures, in order to draw attention to the delays. "Detailed Operations" and the several delays of each character on the different production-operation sheets are totaled and entered in the proper space and column on the summary sheet. For instance, in Fig. 13 trouble due to the feed pipe clogging—

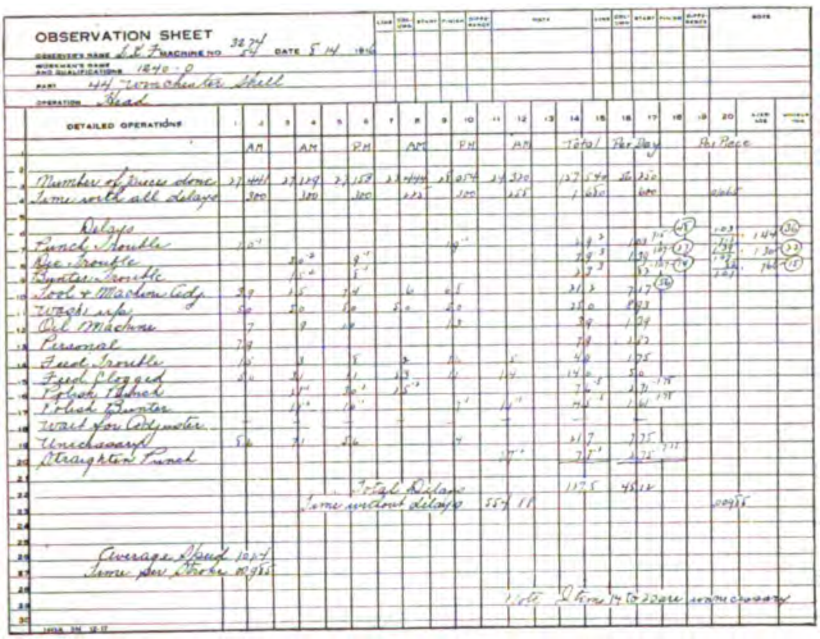


FIG. 14. ANALYSIS OF TIME STUDIES ON AN AUTOMATIC HEADING PRESS

indicated by the symbol *FC*—occurred quite frequently. The time lost through such delay was totaled and entered on line 16 of the sixth column of the summary sheet. Similarly, the time lost unnecessarily is totaled, found to be five and six-tenths minutes, and recorded; likewise the seven and four-

tenths minutes consumed in adjustments, etc. The entry of the time consumed in polishing the punch—line 17, sixth column —carries the exponential figure, "2," to indicate that the polishing was done twice during the afternoon of the study.

In analyzing the observation sheets and recording the totals on the summary sheet, the delays that are deemed as necessary under manufacturing conditions are separated from those that are obviously unnecessary, as shown in the illustration (Fig. 14).

Analyses are made of each of the production-observation sheets, the data properly recorded on the summary sheet, and then the length of the working day in minutes—600 in the establishment at which the study under observation was taken —divided by the total time taken in making the observation, including all delays, to obtain a factor that will reduce the totals of production and delays to a standard production and delay record for a single day. Thus, the heading operation study required 1,680 minutes (see Fig. 13) for its completion, giving a reduction factor of 0.357, so that the delay of fourteen minutes, due to the clogging of the feed pipe, which occurred during the study, reduced to five minutes per day.

Studies were also conducted on similar machines doing work of the same character but of different size, namely, 0.32 and 0.38 caliber cartridge cases, in which the same character of delays took place, as is shown in the analyses tabulated in Table C.

The data thus presented indicates that certain delays are apparently common to all sizes of cartridge cases: for instance, delays due to trouble with the feed, punch, die, and bunter, adjusting and oiling the machine, and those of a personal nature. It can be assumed, therefore, that such delays are an unavoidable part of the manufacturing process and may be expected to occur with more or less regularity. Forming, as they do, a large percentage of the total delays, they should be examined carefully—first, to ascertain whether they can be wholly or partly avoided, and, second, to establish the proportion of the total delay represented by each cause when reduced to its minimum. The miscellaneous and abnormal delays are obviously due to accident or carelessness and need not be considered in the setting of tasks. In fact, they need not be considered at all, except to see that provision is made to prevent their occurrence.

The fact that the delay due to feed trouble is irregular in character indicates that it is due to conditions that are not inherent in the manufacturing process, and that they, there-

TABLE C. ANALYSIS OF DELAYS IN TIME STUDY OF AUTOMATIC HEADING PRESSES

	Total						Per Day					
	0.32 Caliber Case		0.38 Caliber Case		0.44 Caliber Case		0.32 Caliber Case		0.38 Caliber Case		0.44 Caliber Case	
Production	118,292		121,636		281,651		47,441		43,838		51,205	
Time, min	1,485		1,665		3,330		600		600		600	
Delays	**Changes**	**Min.**	**Changes**	**Min.**	**Changes**	**Min.**	**Changes**	**Min.**	**Changes**	**Min.**	**Changes**	**Min.**
Feed trouble	....	48.0	....	92.80	....	46.58	....	19.37	....	33.40	....	8.47
Punch trouble	6	96.5	6	51.75	5	23.20	2.4	39.02	2.2	18.60	0.91	4.22
Die trouble	....	....	4	55.40	4	31.70	....	.....	1.4	19.90	2.62	5.76
Bunter trouble	7	32.8	4	35.35	5	29.10	2.8	13.25	1.4	12.70	1.18	5.28
Adjust machine	....	49.9	....	88 30	....	153.40	....	20.16	....	31.80	....	27.90
Wait for adjuster	....	45.2	....	....	....	26.00	....	18.26	....	......	....	4.74
Oil machine	....	1.5	....	....	....	6.30	....	0.61	....	......	....	1 14
Unnecessary	....	19.7	....	108 05	....	42.90	....	7.86	....	38.95	....	7.80
Wash	....	10.0	....	20.00	....	50.00	....	4.04	....	7.25	....	9.10
Belt trouble	....	....	....	....	....	37.10	....	.....	....	......	....	6 75
No operator	....	....	....	....	....	....	....	.....	....	......	....	1.32
Tools needed	....	....	....	15.40	....	....	....	.....	....	5.55	....	.....
Gaging	....	....	....	7.50	....	....	....	.....	....	2.70	....	.....
Machine Repairs	....	....	....	21.20	....	....	....	.....	....	7.65	....	.....
Polish punch, die and bunter	....	9.6	....	....	....	9 00	....	3.88	....	......	....	1.64
Unavoidable	....	....	....	3 55	....	....	....	.....	....	1.28	....	.....
Bad shells	....	....	....	10.50	....	1.60	....	.....	....	3.78	....	0.29
Change job ticket	....	....	....	....	....	7.80	....	.....	....	......	....	1.42
Total delays		313.2		509.80		471.80		126.50		183.56		85.83
Net productive time		1,171.8		1,155.20		2,828.20		473.50		416.44		514.17

fore, probably are subject to correction which would eliminate this source of delay altogether. As a matter of fact, an investigation of the equipment after the production-time study had indicated the irregularity of the feed revealed that the feed pipes through which the shells were fed to the presses from the magazines were too small and clogged easily. The substitution of larger feed pipes removed practically all trouble from this source and automatically eliminated this particular item of delay.

The delay occasioned by trouble with the punch, die and bunter and that due to adjusting the machine can be further subdivided (see "Production Observation Sheet," Fig. 13). Such divisions are listed in Table D, in which the delays occurring on 0.32 and 0.44 caliber are differentiated in detail.

TABLE D. SUBDIVISION OF DELAYS

	0.32 Caliber Case		0.38 Caliber Case		0.44 Caliber Case	
	Total Delay, Min.	Delay per Day Min.	Total Delay, Min.	Delay per Day, Min.	Total Delay, Min.	Delay per Day, Min.
Change punch	86.3	34.90			7.1	1.29
Polish punch	10.2	4.12	51.75	18.6	19.9	3.62
Straighten punch	....	.....			2.1	0.38
Change die	....	.....	55.40	19.9	4.3	0.78
Polish die	....	.....			27.4	4.98
Change bunter	....	.....	35.35	12.7	9.2	1.66
Polish bunter	32.8	13.25			19.9	3.62

In the case of the 0.38 caliber case, the divisions are not so fine, as the observer failed to analyze the interruptions as closely. However, the information secured in the time studies on the other two sizes is sufficient to enable a reasonable deduction regarding the delays on the third size.

Interruptions incident to punch, die and bunter troubles divide themselves into two classes—changing the tools and polishing the tools. The one apparent exception is the delay occasioned for straightening the punch in the operation on the 0.44 caliber cartridge case, and this can properly be included in the time for changing tools, as it is an adjustment incidental to the improper setting of the punch. An investigation of the reasons for the quite frequent polishing of the punch, die and bunter established the fact that it was more or less a tradition and largely unnecessary. Any polishing that might be needed could be done at the time the tools were changed, so the stopping of the machine at irregular intervals for this purpose was wholly unnecessary and a waste of

time and effort. These delays were disregarded, therefore, in formulating the task.

The only interruptions to the smooth, continuous operation of the heading machine which should be allowed are, then, the delay incident to changing the punch, die and bunter, adjusting and oiling the machine and the usual flat allowances for personal delays and washing. These allowable delays are listed on the summary sheet, Fig. 15. It will also be noted that the speed of machine is set at 110 r.p.m. on this sheet, although the

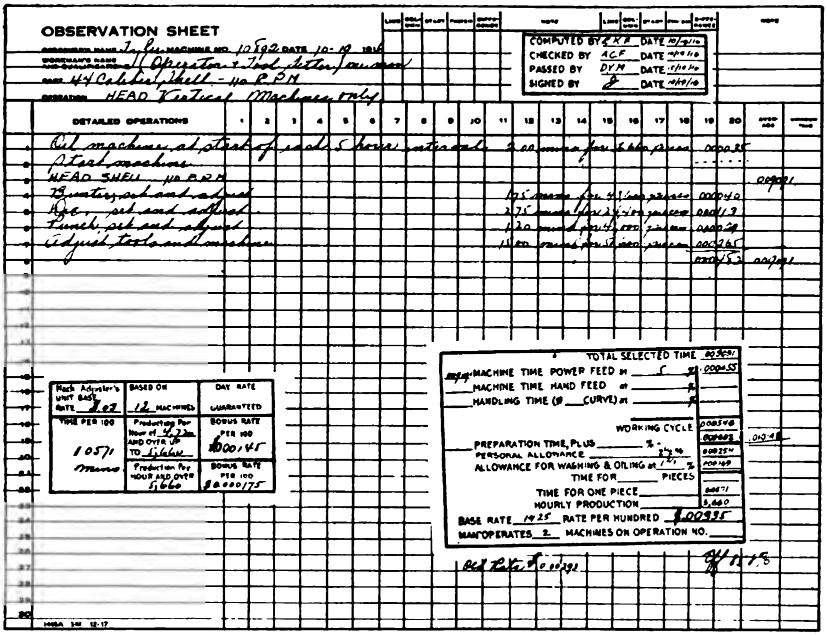


FIG. 15.—SUMMARY OBSERVATION SHEET OF TIME STUDY ON HEADING 0.44 CALIBER CARTRIDGE CASES

time studies showed an average speed of about 100 r.p.m. The higher speed was determined upon as the result of an independent investigation carried on to ascertain the maximum speed at which the operation could be effectively performed, taking into consideration the effect of the process on the material employed, the frequency of breakdown of equipment at the several speeds investigated, the life of punches, etc. Such an investigation is highly desirable, but not altogether necessary from the standpoint of time study. The delay allowances could be fixed just as accurately without such an investigation, al-

though there then would be no assurance that the presses were delivering their maximum capacity. This investigation is of a mechanical character and should be made to supplement the time study whenever possible.

To determine how often the punches, dies and bunters should be changed and the length of time that should be allowed for each change—unless there are a great number of observations available—is a more complicated problem and it is unwise to attempt to formulate a particularly severe task for this portion of the work. Changes are bound to come at such irregular and relatively infrequent intervals that no regular rate of speed for accomplishing the task can be established, nor is there any chance for the operator or adjuster to develop a rhythm in this work that will tend to diminish the time required. When series of studies have been taken on a single type of machine, it is probably safe to take the average value, both of the number of changes and of the time consumed in making a change as typical, and to use such averages as bases upon which to figure allowances for delay, fatigue, etc.

Where several machines are involved, however, or several sizes of work—as in the investigation under consideration—it is advisable to plot curves from the results obtained from the time studies and, from such curves, select more or less arbitrary values for the duration of the delays deemed permissible for the different sizes of work, etc. Fig. 16 illustrates the curve procedure in the case of ascertaining the necessary number of punch changes and their duration, for the various sizes of cartridge cases in the heading operation. Points 37 and 38, adjacent to the upper end of the lower curve, indicate the average time consumed per change, as determined by two separate studies of machines working on 0.32 caliber cases; points 31 and 32, near the center portion of the curve, similar data for machines on 0.38 caliber cases; while the four points 33, 34, 35 and 36 register the average times consumed in making a change on machines operating on 0.44 caliber cartridge cases, as ascertained from as many studies. The points 100, 101 and 102 represent respectively the mean of the several values plotted for the machines operating on 0.32, 0.38 and 0.44 caliber cases. The curve which would pass through the three mean value points is so flat that a straight-line approximation of it is sufficiently accurate for all practical purposes, so a straight line—dividing the error equally on either side of it—was drawn to establish the probable, and therefore allowable, time per change for the different sizes of work. The values selected for the

delay allowances for changing punches are indicated at the points of intersection *E*, *K* and *J* of the straight line, with the ordinates representing the several sizes of cartridge cases.

The straight-line curve, *FLR*, the upper of the oblique lines shown in Fig. 16, was laid out in a similar manner and gives

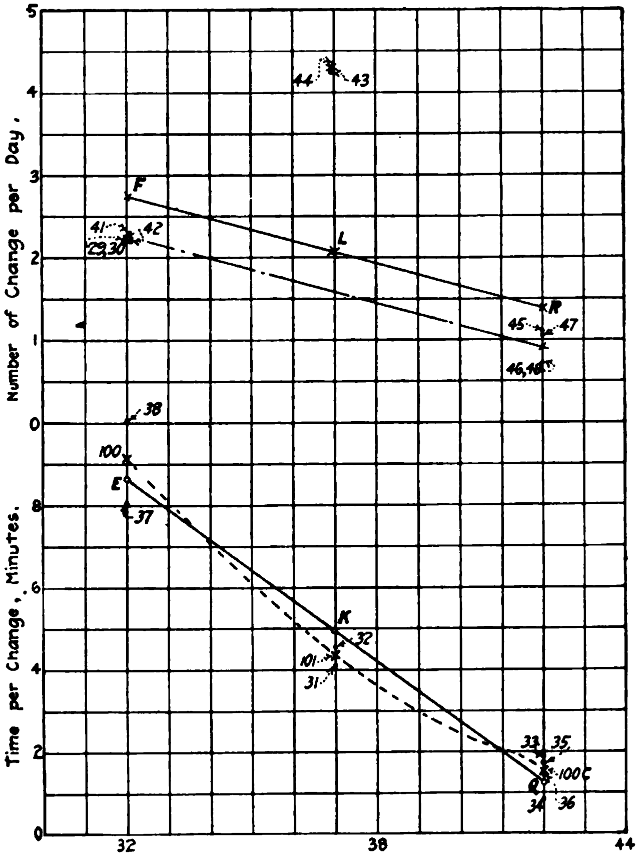


FIG. 16.—GRAPHICAL ANALYSIS OF NECESSARY DELAYS FOR PUNCH TROUBLE

the average number of punch changes per day for the various sizes of machines. Approximation curves are drawn in the same way to obtain values for all other of the necessary and allowable delays (Figs. 17, 18 and 19): namely, die and bunter trouble and machine-adjustment delays.

The establishment of a reasonable delay allowance for neces-

sary die trouble (Fig. 17) is complicated by the facts that no die trouble was experienced during the two days' study of the two machines operating on 0.32 caliber cartridge cases, the interruptions of the machines working on 0.38 caliber cases of relatively long duration and the interruptions of the machines employed for the 0.44 caliber cartridge cases of correspondingly short duration. The reasonable deduction is that the size of

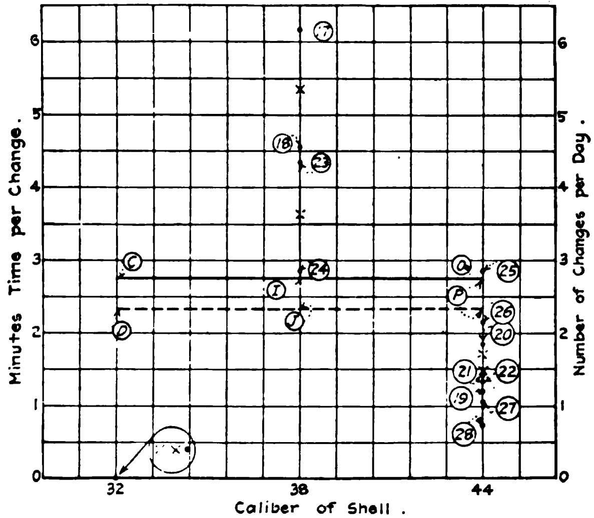


FIG. 17.—GRAPHICAL ANALYSIS OF NECESSARY DELAY FOR DIE TROUBLE

the work—diameter of cartridge case—is not a controlling factor in establishing a reasonable allowance for die trouble, and that the rather serious interruptions to the machines on 0.38 caliber cases are no more typical than the absence of interruptions to the machines on smaller work or those of markedly shorter duration to the machines employed for the 0.44 caliber cartridge cases. As an allowance for die trouble is deemed necessary, a definite allowance—a mean of the interruptions which occurred to the machines on 0.38 and 0.44 caliber cartridge cases—was decided upon for the machines working on all three sizes of cartridge cases, as depicted by the horizontal-line curve of Fig. 17.

Arriving at the logical delay allowances for necessary bunter troubles, for the respective sizes of cartridge cases, was justly simplified by disregard of the two delays to the machines on 0.38 caliber cases, which were quite obviously unreasonably long. It was evident that the delays occasioned by bunter

trouble were much less serious in the case of machines working on 0.44 caliber cartridge cases than the delays to machines on smaller cartridge work. The bunter-delay allowance, therefore, for the machines on the various sizes of cases was established by the oblique straight line connecting average mean values for the delays occasioned on the

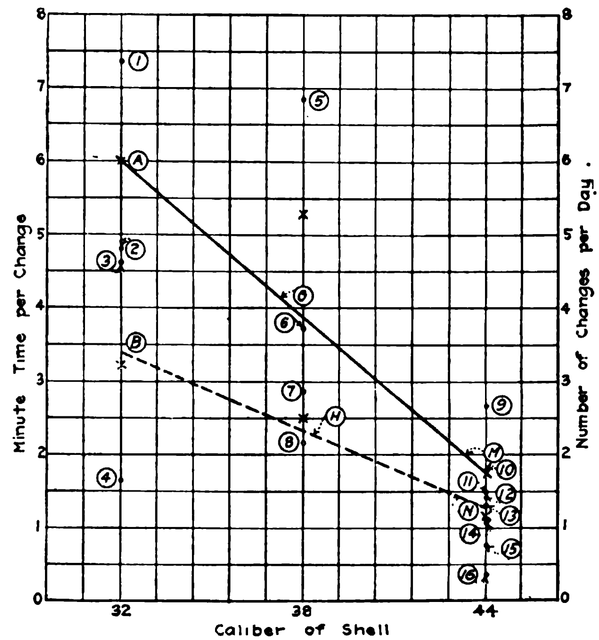


FIG. 18.—GRAPHICAL ANALYSIS OF NECESSARY DELAYS FOR BUNTER TROUBLE

machines working on 0.32 and 0.44 caliber cartridge cases, as shown in Fig. 18.

The data pertaining to delays caused by miscellaneous tool and machine adjustments is likewise erratic, the interruptions in the case of the machine on 0.38 caliber cartridge cases being quite evidently of unduly long duration, those to the equipment employed for the 0.44 caliber cartridge cases shorter than might be expected and those to the machines working on 0.32 caliber cartridge cases somewhat long. Since, as in the case of die trouble, it would appear that the size of the work should be in no way effective in governing the duration of the delays, a common mean machine adjustment-delay allowance was decided upon as indicated by the horizontal line of Fig. 19.

The reasonable delay allowances, determined in this manner were entered on the observation sheet (Fig. 15), and the

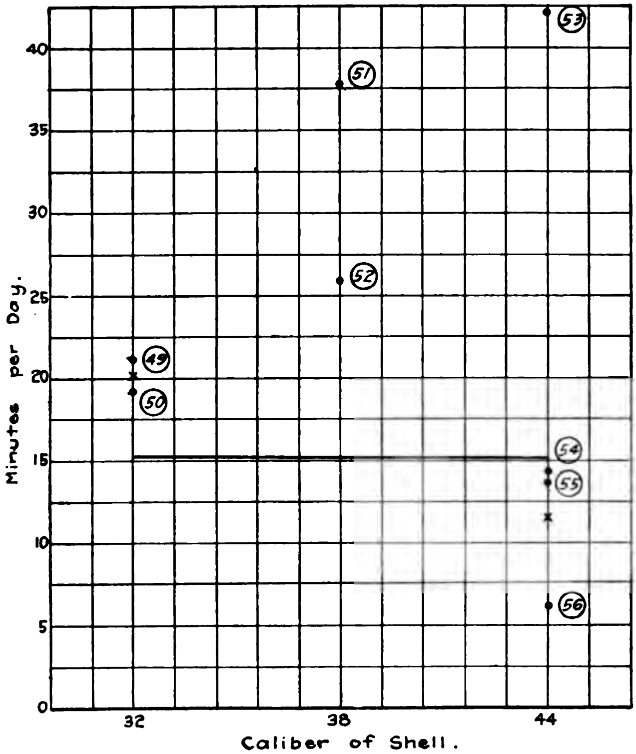


FIG. 19.—GRAPHICAL ANALYSIS OF NECESSARY DELAY FOR MACHINE ADJUSTMENT

production per day ascertained by means of a convenient formula, as follows:

$$Production = \frac{Q}{1.05}(M - 1.25H - W - P)$$

where

Q = Production in pieces per minute, or revolutions per minute of the machine when the production is one unit per revolution;

M = Number of minutes in the working day;

H = Sum total of all adjusting, oiling and tool-setting allowances in minutes per day;

W = Washing allowance, in minutes per day;

P = Personal allowance, in minutes per day.

The denominator 1.05, of the factor, and the coefficient 1.25 represent respectively the allowance for the speed and feed of the machine work and for handling time.

The statement in Chapter II will be recalled, that a flat allowance of 5 per cent. was made on all machine time and that an allowance for handling time was determined by means of the curves illustrated in that chapter. Reference to those curves will show that when the period exceeds 10 min. the curves are practically straight and the delay allowances range in value from 20 to 30 per cent. An average allowance of 25 per cent., therefore, has been considered ample for this class of work. Translated into the terms of a 10-hour day, on machines running 110 r.p.m. and delivering one unit of product per revolution, the above formula would read

$$Production = \frac{105}{1.10}\,(600 - 1.25H - W - P)$$

When the production has been found by means of the formula, the various quantities that can be made by each portion of the equipment between changes are ascertained by dividing the production per day by the number of changes per day. The quotient so obtained is divided into the time allowed per change, to apportion the delay to the individual piece, and the results are entered in the summary sheet (Fig. 15) as shown. These delays and the prorated allowance for machine and handling time, together with the personal and washing allowances, are added to the machine time per piece to give the total time to produce a single piece, with all delays and allowances figured in. The hourly production and unit piece rate are then calculated, as shown in Fig. 15, and instruction cards written and issued.

The instruction card issued to the machine operator (see Fig. 20) enumerates the detail operations, with the time the work should take and itemizes the various allowance times; it indicates also the number of machines the operator should attend to and the rate of payment per machine and per unit—the heading of the cartridge cases being conducted on a piece-work basis. The instruction card to the machine adjuster (Fig. 21) lists in detail the tasks he is supposed to perform and gives the bonus offered for keeping the twelve machines allotted to him in such condition as to enable the machine operators to maintain output on all machines. The interests of both the machine adjuster and the machine operator are thus in large measure

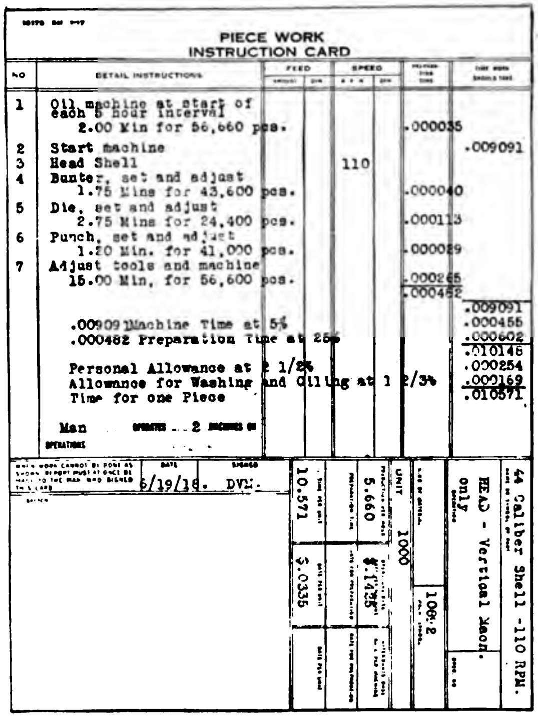


FIG. 20. INSTRUCTION CARD ISSUED TO MACHINE OPERATOR

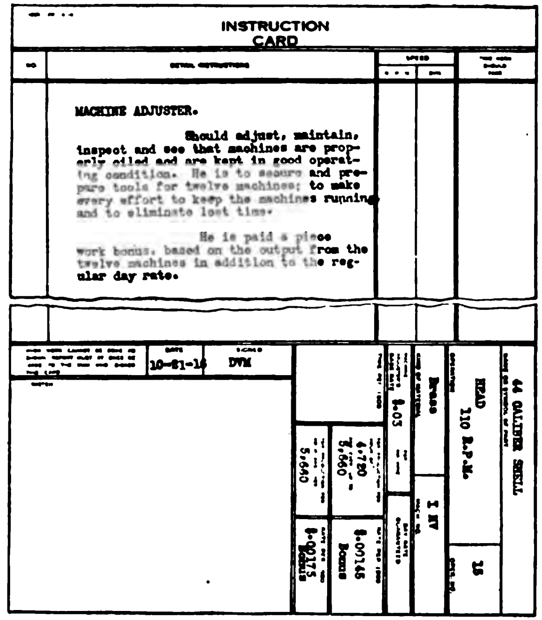


FIG. 21. INSTRUCTION CARD ISSUED TO MACHINE ADJUSTER

mutual, and this tends to that co-operative activity which assures output.

While the foregoing detailed explanation applies to time studies on automatic-press work, nevertheless the principles involved apply to studies on practically every class of automatic machinery. The advisable procedure may then be summarized as follows:

1. Take a study of one or several machines of the same character, extending over several days, noting the production at regular intervals and recording the time of the beginning and ending of each interruption or delay, together with a notation of the nature of such interruption or delay.

2. Analyze the delays and interruptions, noting the number, total and individual times of each class of delay for each size of machine or size of work.

3. Examine the delays to ascertain which are avoidable by correction of existing improper conditions and discard these from consideration, after taking steps to have the improper conditions rectified.

4. Plot the remaining delays to ascertain whether or not any relation exists between them and also to ascertain what effect one character of delay has upon another.

5. Subdivide as minutely as possible these delays and examine them to see if any portion of them can be avoided. If so, discard these items from further consideration.

6. Plot the average time, in minutes, of each class of delay and draw a smooth curve that will represent the average performance of the group of machines or several sizes of work under consideration, and read from the curves the allowable time per delay.

7. Plot in a similar manner the average number of delays per day for each class and determine the allowable number of delays per day.

8. Multiply the number of allowable delays per day by the time per delay, to ascertain the total length of each class of delay per day.

9. Determine the required production per day by means of the formula,

$$Production = \frac{Q}{1.05}(M - 125H - W - P)$$

10. Divide the production per day by the number of delays per day of each class (as found in 7), and divide the quotient

into the allowable time per delay (as found in 6), to prorate the total delay to the individual piece.

11. Ascertain the machine time per piece by dividing the total production per day into the number of minutes in the working day.

12. Add the machine time per piece to the total of all the delays per piece, and add to the sum an allowance of 5 per cent. of the machine time per piece and of 25 per cent. of the sum of all the delays per piece.

13. Add to the sum obtained in (12) the prorata allowance per piece for the various personal necessities and washing.

14. Divide the sum obtained in (13) into 60 to find the hourly production required.

15. Fix base rates and task for daily or hourly production.

CHAPTER V

ESTABLISHING DELAY ALLOWANCES FOR RATE SETTING

THE taking of time studies for rate setting simply furnishes a gauge by which a definite task can be measured. Accurately determined allowances are established by which the time in which the task could be performed under ideal conditions by a highly skilled worker (minimum selected time) is increased to bring the time set for the task (task time) well within the ability of the average worker. The measure of the fairness of a task is the ability of the worker to complete it consistently in slightly less than the task time—that is, in the time the task could be performed by a skilled and effective worker under unusually favorable conditions plus the reasonable time allowances provided for anticipated necessary delays and a reduction in the efficiency of the worker if he were called upon to work continually at the pace at which he could work for a few minutes—*i. e.*, his best rate for a short period.

Time study aims, in its broad sense, to establish such a rate of work that the worker will accomplish a maximum amount of work with a minimum amount of fatigue. Only under such conditions can the desired high rate of production be maintained hour after hour and day after day. The necessity for time study, if the best possible results are to be secured from the activity of every worker, and not merely from a few selected of unusual skill, arises from the fact that the average worker has no true conception of his productive ability nor of the easiest way to perform his work. Time study measures his productive ability, teaches him how to work in an easy and efficient manner and then—and only then—sets a task.

To select the minimum selected time in which a task should be accomplished under ideal conditions, as has in the past been the common erroneous understanding of the main object of time study for task setting, would be to select an exceedingly high standard of performance, well beyond the ability of any but the most skillful and, therefore, exceedingly unfair. The addition of suitable time allowances to the selected minimum time, however, brings task setting into quite another category.

Time study sets a rate which the average worker should be able to better consistently, and though the best workers may be able to complete the task in a time approaching the minimum selected time, even the poorer workers should be able to do it within the task time.

The determination of the allowance factor was at first an arbitrary selection of a value intended to cover all the operations within certain classes of work, but subsequent development in time study investigations made it evident that other factors had to be considered than simply the class of work. For instance, the length of the cycle of operations was found to bear considerable effect upon the allowance factor. Likewise, a task which involves only machine work requires a very different allowance than one which is made up wholly or in part of manual operations. Work done in a cleanly, well-lighted and ventilated shop, maintained at a comfortable temperature, will call for a smaller allowance than work carried on under less auspicious conditions.

Originally, the allowance was referred to as a "fatigue allowance," but such nomenclature is quite misleading, for the influence of fatigue in reducing rate of production varies to a very marked extent with the character of the work. While it is quite true that fatigue plays an important part in reducing output in certain classes of work, in others it has comparatively little influence. In machine work, where the tasks are long and the operator has little to do but watch the machine, the influence of fatigue is very nearly negligible, while variations in machine speed, quality of tools, condition of material worked upon and numerous other factors prove of much greater importance in the correct formulation of the allowance which should be made. On the other hand, in the case of a blacksmith swinging a heavy sledge or a man doing a great deal of metal chipping, fatigue is probably of far more importance in diminishing the amount of work which can be accomplished than any other one factor.

A task which is made up of a series of related operations that recur in a regular sequence at periodic intervals enables the operator to establish a rhythm in his work which cuts down materially the amount of allowance required. The more nearly the operator approaches a perfect rhythm in his work, the less will be the needed allowance. On work entailing more or less interruption, such as tasks requiring the intermittent or occasional stopping and re-starting of the machine for incidental operations or attention, the allowance should be greater than

on work not subject to such interruptions, for the rhythm of the productive work is invariably destroyed. Such breaks in the continuity of the work have frequently a tendency to increase fatigue, rather than to lessen it, for the interruptions may not serve as rest periods, as is sometimes the case, but simply check the effective cycle of actions which develops high output with a minimum expenditure of energy. The qualified statement is made here, as interruptions in the way of change in nature of work are not infrequently introduced to guard against fatigue.

The influence of fatigue as a detracting factor in attaining high production was duly considered by Frederick W. Taylor in his management work, and he made many studies to determine the point at which fatigue commenced to affect the output of a worker. These early studies of Doctor Taylor were similar to that conducted to demonstrate the value of fatigue allowances to an operator who was skeptical as to the effect of fatigue on his particular work. the results of which are graphically depicted in Fig. 22. While this study indicates the value of rest periods in certain classes of work, it is not of sufficient scope to give any reliable information for making allowances on a broad line of work. The study illustrated extended over but two days and was on a single operation. To have been suitable for general use, it should have covered a much wider range of work with different operators and should have extended over a much longer period and under varying conditions.

The operator was allowed to work straight through, from starting time in the morning until noon, without stopping to rest, and for another four hours in the afternoon. He was allowed to set his own pace as he became tired and to take longer for each operation as he grew more fatigued. The length of time required for each complete cycle was recorded as the work progressed and the data used to plot the graphs in Fig. 22. The experiment was in reality a production study conducted in a manner not to be recommended except for an experiment intended to disclose facts. Proper provision was not made to avoid fatigue, so the output of the worker necessarily decreased during the day and toward the end of the afternoon was seriously reduced. The particular task selected for the experiment was one in which the entire operation was composed of handling time. A machine was used; but as it was manually operated, the work falls in the classification of all handling time. A previous time study had established a minimum selected time of something under half a minute per complete

cycle, but as the minimum selected time would have set too severe a rate, a task time of 0.50 minute was set as the standard desired and on which the fatigue allowance should be based.

On the following day the operator, though still allowed to set his own pace, was compelled to take a rest of 2½ minutes every half hour, while engaged in the same kind of work performed on the previous day without rest. On the second day, the work, though of the same kind, was possibly of slightly more difficult character, yet was performed much more expeditiously. The results of the two-day experiment are plotted in Fig. 22,

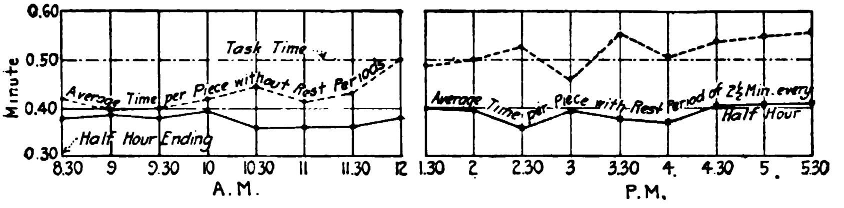


FIG. 22. EFFECT OF A REST PERIOD ON THE TIME OF PRODUCTION

the dotted lines depicting the average time consumed per cycle without rest periods, and the full lines the average time with the regular 2½-minute rest periods each half hour. The points on the various ordinates represent the performance during the respective preceding half-hour periods.

Although, on the first day, the operator succeeded in performing the day's work at an average rate slightly less than that set by the task time, without rest periods, on the second day he did similar work in some eighty per cent. of the time required for actual work during the first day. That is, despite the fact that forty minutes were taken for rest on the second day and nearly thirty minutes additional were wasted due to a machine breakdown, the actual number of pieces produced by the operator was over 10 per cent. greater than the number produced the previous day, when there were no interruptions for rest or any machine trouble.

The data depicted in Fig. 22 would at first appear to supply all the information needed regarding fatigue allowances for the particular task. It gives information as to the maximum rate of speed at which the operator can work, the length of time he can maintain the speed. It also indicates the point at which the first rest period should be introduced and, in addition, it shows the diminution in output that may be expected

if rest periods are not provided. It does not show, however, how long the rest periods should be, how often they should be provided, and what relation they should bear to the character of the work. Were these latter considerations known, allowances could be predetermined even for jobs which had not been previously studied, and their application in practice would develop highly effective and efficient performance. It is quite evident, then, that the determination of the proper interval between, and the length of, the rest periods can only be determined by trial and error with the methods illustrated in Fig. 22, repeating the study over and over again with rest periods of varying lengths and at different intervals. This is at best a cumbrous, expensive and time-consuming proposition.

Instead of providing rest periods, a change in the monotony of the job may effect the same result. In actual practice it may prove unwise from the standpoint of discipline actually to stop production for the purpose of providing forced rest periods. The same object may be accomplished by introducing a rest period under the guise of nonproductive elements. Thus, an operator on a high-speed machine may be required at certain intervals to move his finished product to a different location or to go some little distance for his supply of raw material. The change in the nature of the work involved in this procedure provides for the muscles employed in the productive operations the necessary relaxation to overcome the fatigue produced by the work. The introduction of rest periods in this manner is a matter for the man who prepares the instruction cards, and considerable ingenuity may be exercised by him in this respect.

In certain classes of work, as the operation of automatic machinery, it is often desirable to provide an additional operator to each group of six to twelve workers. This operator takes the place of each of the workers successively, thus providing an opportunity for rest or for attending to their personal needs without stopping production. This additional operator may be the instructor or supervisor for the group.

Another method of relieving the monotony of a task is to interchange the operators on two machines engaged on different jobs of the same general character of work every hour or two. This scheme tends to create a certain rivalry between the workers as well as to stimulate production through the change in work, for it is natural for the operator relieving a fellow worker to leave his former job with a record of performance difficult

for his substitute to better and to attempt, on his new job, to better the record established by the first worker. The other man is just as keen to show that he is as efficient as his co-worker and a friendly spirit of rivalry ensues that is productive of excellent results.

The only approved method of arriving at the information necessary to establish fair and equitable fatigue and delay allowances, however, is to carry on exhaustive and comprehensive production studies as a part of the time-study routine, analyse the data secured and deduce definite allowances therefrom.

The jagged production line shown in Fig. 23 is a record of such a production study extending over a period of several days, on several different jobs of the same character. The ordinate values represent the time consumed for production per piece, and the abscissa scale measures the time of day at which the successive pieces were completed. In recording the production time as bounded by the jagged line, only the net time consumed in productive work is used, avoidable delays being subtracted. It will be observed that above the line of production there are a number of points plotted. These represent the actual time of production, and the distance between them and the corresponding point on the production line represents the avoidable delay that has been deducted. It will be observed also that the time of production per piece has a tendency to increase somewhat as time passes and the end of the day approaches.

One of the earliest attempts to establish a scientific basis for fatigue allowance was the making of a formula to govern this feature. In one of the first shops to use time study, data were gathered as to the percentage by which the actual time of performing jobs on the heavier tools exceeded the minimum selected time, and the following allowances were deduced:

Type of Machine	Size	Percentage To Be Added to Minimum Time	Remarks
Lodge and Shipley lathes..	24 to 30 in.	35 to 50	On 24- to 30-in. lathes, the allowance is 35 per cent. when handling time is more than 8 min. and machine time double handling time; 50 per cent. when handling time is less than 8 min. and machine time about equal to it.
Lodge and Shipley lathes..	48 in.	30	
Vertical boring mills......	120 in.	25	
Vertical boring mills......	36 in.	35	
Vertical boring mills......	30 in.	40	
Horizontal boring mills ...	No. 74 Bennse	40	
Planer..................	36 in.	40	

Similar data on light tools, such as vertical drilling machines,

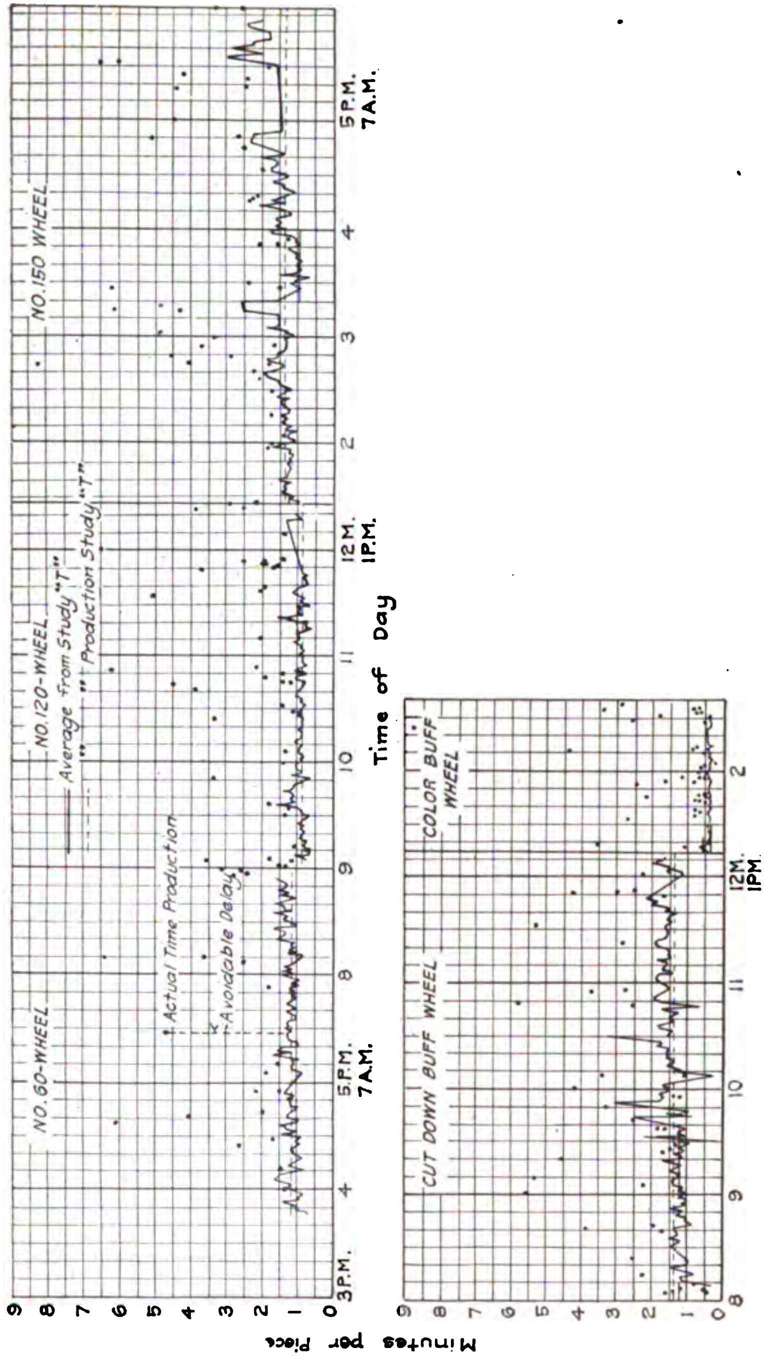


FIG. 23. GRAPHIC RECORD OF FATIGUE STUDY EXTENDING OVER SEVERAL DAYS

etc., were incorporated into a formula by Carl G. Barth, as follows:

$$P = \frac{125}{1.20 + \sqrt{T}} + 20$$

in which P is the percentage by which the minimum selected handling time is to be increased and T is the minimum selected handling time.

The allowances, as given by the foregoing table and formula, while fairly satisfactory for the particular shop at which the studies were made, proved to be inaccurate when applied to shops in different lines of work. It was evident that a broader method of ascertaining allowances was necessary, if they were to be applied along more general lines.

A hypothetical case may be presented to illustrate the approved method evolved. Production studies are made of a number of jobs requiring various lengths of time for their completion, but in which the percentage of handling time is the same. In these studies, the handling time is carefully noted and separated from the machine time, and the total of the handling time in each cycle is expressed as a percentage of the minimum selected time of that cycle. For example, if the total minimum selected time for a job was 1.06 minutes, made up of a machine time of 0.54 minute and a handling time of 0.52 minute the following figures obtain for handling time in several successive cycles: 0.56, 0.64, 0.67, 0.63, 0.65, 0.68 minute. These would then be expressed as percentages of increase over the minimum selected handling time of 0.52 minute, as 26.9 23.1, 28.8, 21.1, 25.0, 30.7 per cent.

The percentage increases of the actual handling time over the minimum selected handling time are plotted with percentages as ordinates and the length of cycles in minutes as abscissas. A curve that will represent the mean of all the points is then drawn through the field, and from it values may be taken which will be a fair allowance for all work with the same percentage of handling time as the jobs on which the curve was based.

The method of laying out the curve is shown in detail in Fig 24, which is a hypothetical case representing results of a large number of production studies on jobs in which the handling time is 50 per cent. of the total time of the cycle—that is, half the operating time is devoted to machine work and the other half to manual operations. The jobs have cycles covering periods varying from 0.5 minute to 8 minutes, and the percentage

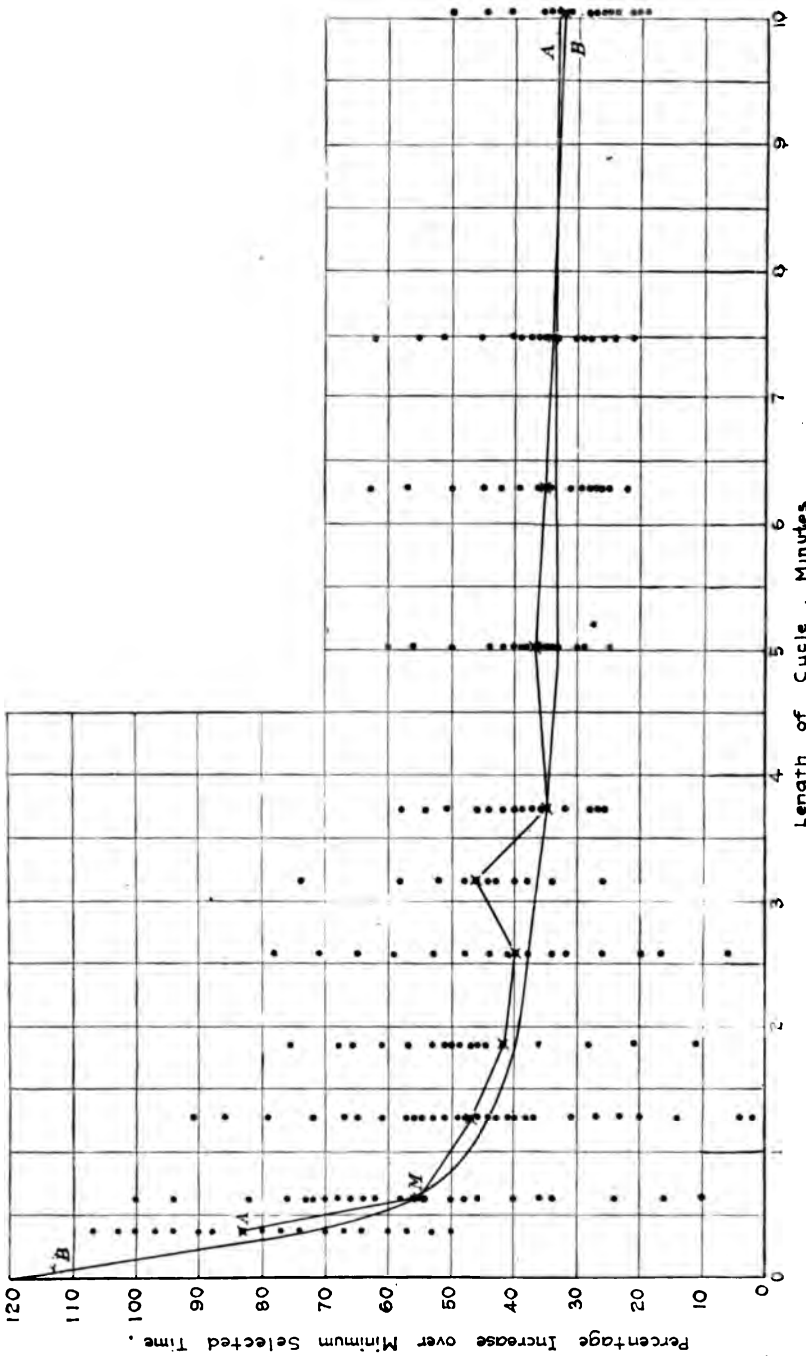


FIG. 24. METHOD OF MAKING FATIGUE CURVE FROM PRODUCTION STUDY

excess of the actual handling time over the minimum selected handling time for each of the several cycles in each of the jobs is shown as the elevation of the respective plotted points above the production line.

To derive the smooth curve establishing the definite values for the percentages which should govern the fair and equitable allowance to be made for each definite length of cycle, it is advisable to determine the average value of the plotted points for each length of cycle, as due weight will then be given to values that occur several times or which vary in value but slightly. If a curve is simply struck through the mean of all points, values that occur several times in the same cycle or are quite similar, will have no greater weight than those which occur but once or which are above or below the mean.

In the study under consideration, the average value for each of the cycles is indicated by the crosses in Fig. 24, which are connected by the straight lines to give the rough outline *AA*. With this rough outline as a guide, the smooth curve *BB* is drawn, which deletes the variations in the first rough graph and very closely establishes the definite percentage allowances by which the minimum selected handling time should be increased to establish the suitable handling times.

Similar curves are plotted for numerous jobs with different percentages of handling time, and the shop is then prepared to set tasks and fix allowances with a certainty that the tasks can be accomplished. The final step is to superimpose the curves for the different percentages of handling time and ascertain if they bear a similarity to one another. If the study has been carefully conducted and the data accurately plotted, it will be found that the several curves show approximately the same trend and that it is possible to derive a mathematical formula to which they will all conform. It is usually advisable, where the mathematical ability is present, to derive this formula and to replot the curves in accordance with it.

The curves shown in Fig. 25 represent developments of several classes of production studies that finally evolved into the series shown in Fig. 4, Chapter II. Curve *A*, Fig. 25, represents the curve obtained by plotting Barth's original formula,

$$P = 20 + \frac{125}{1.20 + \sqrt{T}}$$

This cuvre, based on comparatively few observations and a limited number of machine types, gave allowances far in excess

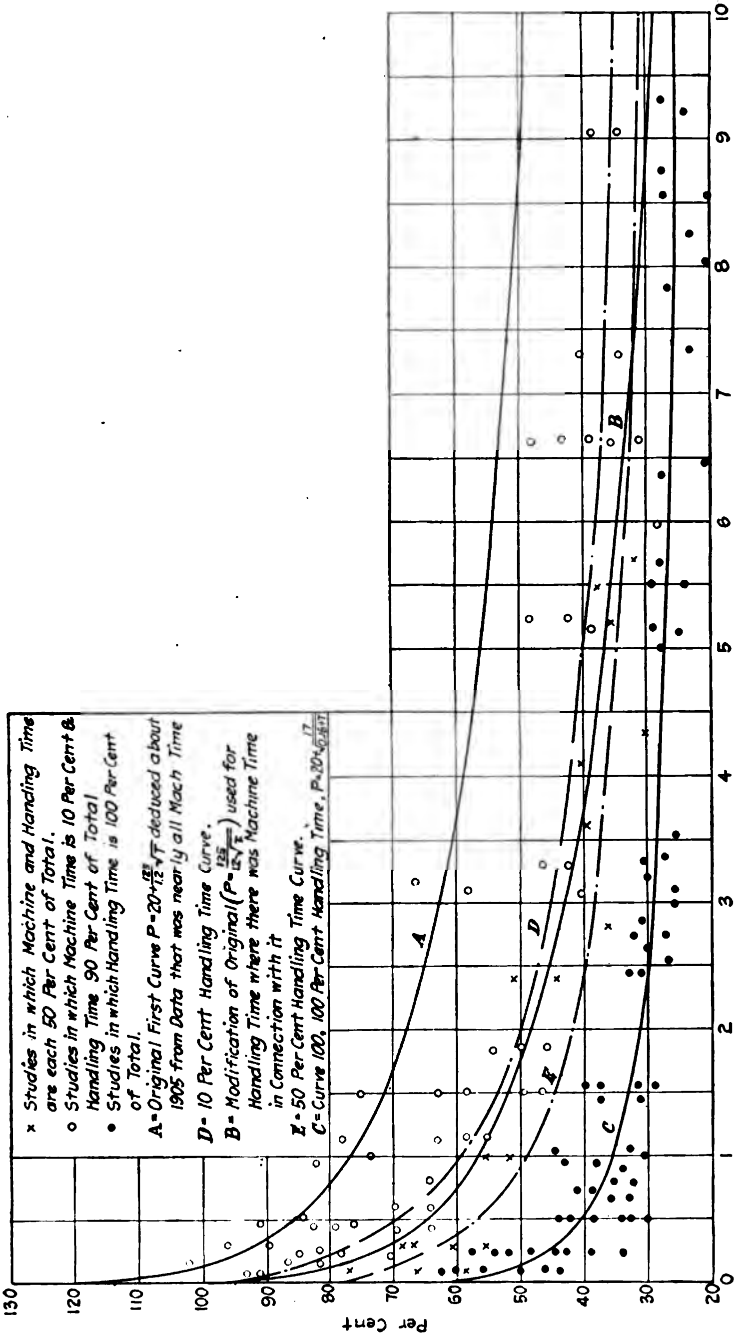


FIG. 25. COMPARISON OF THE EARLY AND RECENT FATIGUE CURVES

of those necessary for certain classes of work. It was later modified to curve *B*, which was used where machine time and handling time occurred in combination. Although curve *B* was much more comprehensive in its scope than the original handling allowance curve *A* it was latter found that still more differentiation should be made between classes of work that varied greatly in the percentage of handling time involved and additional curves were evolved according to the method employed for determining cutve *B*, Fig. 24, for work involving percentages of handling time ranging from 10 to 100 per cent. Typical of these studies are the curves *C*, *D* and *E*, Fig. 25, which represent handling allowances for jobs entailing 100, 10 and 50 per cent. handling time respectively. Similarly the series of curves shown in Fig. 4, Chapter II, were evolved from thousands of careful studies conducted in many different shops and extending over a long term of years. The curves are reproduced with a logarithmic ordinate scale to facilitate the true relative reading of the percentage allowances for cycles of short duration.

The mathematical formula for the whole series of curves, derived by Mr. Barth, is

$$P = 20 + \frac{49.5 - 0.325C}{\sqrt{0.376 - 0.0000216C^2 + T}}$$

in which P is the percentage allowance, C the percentage of handling time and T the minimum selected time for the cycle.

The series of curves presented, representing as they do thousands of carefully taken production studies carefully and systematically recorded and analyzed, are generally applicable to machine-tool practice in the ordinary well-lighted and ventilated shop which is properly heated and in which working conditions are effectively maintained. Where conditions are not so satisfactory or where conditions tend to enervate the workers, additional allowances should be made, and in other classes of industrial activity the most effective allowances may be proportioned somewhat differently, but under any and all conditions accurate allowance curves can be derived by following the methods and procedure previously described.

In using the curves, the particular curve is selected which corresponds most nearly to the percentage of handling time in the cycle on which allowance is to be made. Thus, when there is no machine time involved, curve 100, representing 100 per cent. handling time, is used. If the cycle represented 50 per cent. handling time and 50 per cent. machine time, then curve

50 is used. The percentage allowance is made upon the total of the handling time; that is, if a job comprised 3 minutes of machine time and 2 minutes of handling time, the 40 per cent. curve would be used and the intersection of the 2-minute ordinate with this curve would determine the allowance that would be added to the handling time in making up the instruction card. For machine time with power feed a flat allowance of 5 per cent. is added, and for machine time with hand feed an allowance of 20 per cent. is added to the machine time. The method of making allowances by means of curves derived from data furnished by production studies takes into consideration the delays to the work due to other considerations than fatigue. Even in the most highly organized and best-managed shops, occurences are bound to take place which will delay the progress of work to a certain extent. Some of the delays are avoidable, and others are not, as was explained in the chapter on production studies. The avoidable delays are all eliminated from the record before the percentages that are plotted, as in Fig. 24, are calculated, and only the net productive time, the delay due to fatigue and unavoidable delays that, in all fairness, should be allowed are taken into consideration.

Inasmuch as the curve developed for delay allowances include other factors than fatigue, the term "variation allowance" has been adopted as a better expression than the term "fatigue allowance," which has been so widely used. Fatigue does play a large part in slowing down certain classes of work, particularly where the cycle is short, necessitating frequent and rapid movements on the part of the operator, and where the handling time or period of actual physical exertion on the part of the operator is a large percentage of the total cycle. Its influence is relatively less as the length of the cycle increases and the percentage of handling time diminishes. In such cases, the influence of the unavoidable delays may be greater than that of fatigue. These features are clearly shown by the curves, in which the allowance for the short cycles, where there is little opportunity for the operator to recover from fatigue, calls for higher percentage of allowance, while the long cycles, which offer rest periods in the cycles themselves, call for much lower percentages of allowance.

CHAPTER VI

PRODUCTION-TIME STUDY ON VARIABLE OPERATIONS

THE soundness of the principles of time study upon which rates may be set for work of a repetitive nature, such as the activities upon which time studies may be taken in manners as described in the preceding chapters, are readily conceded, for the nature of the work invites a rhythm of fundamental operations which is repeated time and time again until they can be made almost automatic in their regularity. On automatic and semi-automatic machine work, interruptions to the regular smooth progress of the machine operations need only be investigated to secure the best possible production, as, for instance, on work of the character of the operation studied in Chapter V. There are, however, numerous operations in any shop, mill or manufacturing plant which are not repetitive or which, if repetitive in nature, are so affected by variable conditions as to be classified as variable operations.

In the machine shop, the task of one man or a department is to keep the small tools employed on some machine sharp and in good condition. It is a specific job, but, though the tools cared for may be all similar, it will be found that the amount of work entailed to put them in good shape varies with almost every tool. If the tools have to be ground, as in the case of the heading dies for a cartridge case, it may be found that one die could be lapped in a few minutes, while another, owing to the variation in hardness and the amount of metal to be lapped off, would require an hour or more to be expended in lapping it. To set a definite rate for such character of work is quite possible by scientific time study, provided sufficient observation is made and a suitable incentive is provided the workers to work diligently. Incentive is necessary, for effective work of this nature must necessarily call upon the ingenuity and skill of the operator. It is, obviously, not a task for which detailed instructions, with set unit times for all acts, can be issued. The incentive should be commensurate with the application and skill demanded of the operator.

Typical of the procedure to be followed in arriving at an

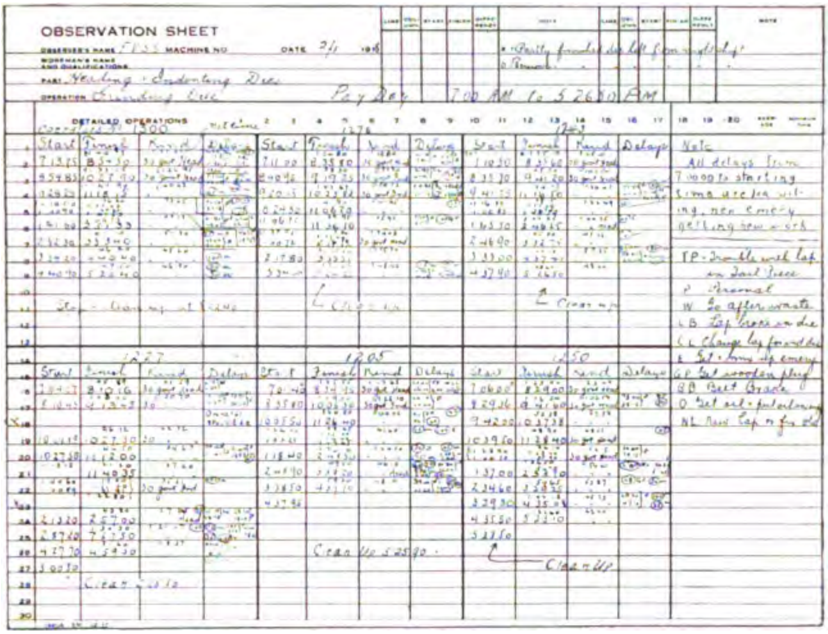


FIG. 26.—PRODUCTION-TIME STUDY OBSERVATION SHEET

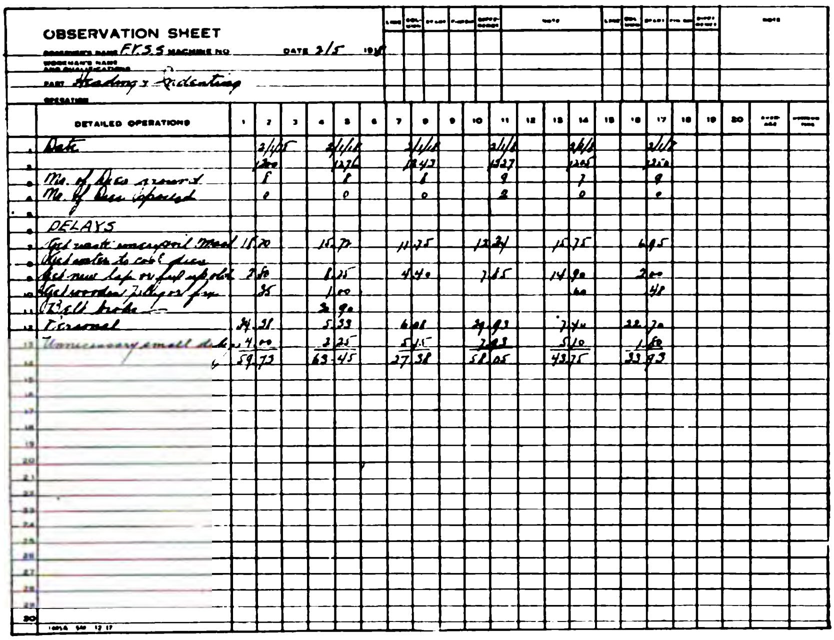


FIG. 27.—SUMMARY OF PRODUCTION-TIME STUDY

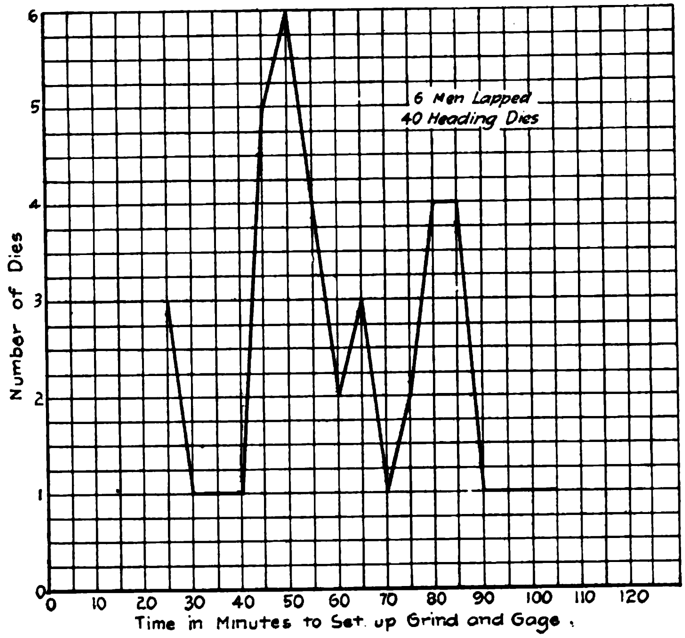


FIG. 28.—PRODUCTION CURVE—FIRST DAY

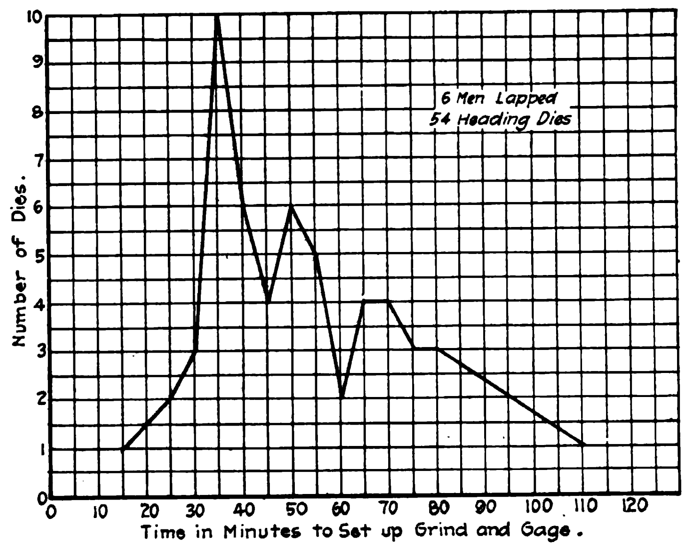


FIG. 29.—PRODUCTION CURVE—SECOND DAY

equitable set time for a variable operation of this character is a time study made on the lapping of a specific size of heading die for certain cartridge cases at a plant engaged in intensive war work.

A production-time study extending over a full day was made on the output of six workers engaged in similar work, and the observed data is given in the observation sheet, Fig. 26. Delays of every kind were noted, with the elapsed times for all interruptions, classified and totaled as in the summary observation sheet, Fig. 27. From the data thus secured, the production curve (Fig. 28) was plotted, after deducting all unnecessary and unusually long delays. During the day the six men lapped 40 heading dies, but the production curve clearly indicated that the operation was one of marked variation, as far as time of accomplishment was concerned, as the grinding of one die took 105 minutes, another 90 minutes, several 85 minutes each, and many more from 25 to 80 minutes. Similar production-time studies were taken on three other days, during one of which six men lapped 54 dies; on the next day, 52 dies; and on the third day 63 heading dies were lapped by the six men. The production curves covering the activity of the three days are shown in Figs. 29 to 31, inclusive. These curves of later output, though indicating that the men were bettering their former records, still showed the marked variation in the time required to lap different heading dies.

An accumulative curve of the four days' time studies was then plotted, as is shown in Fig. 32, which, together with the knowledge acquired from the individual studies regarding delays and drop in output, indicated that if an equitable rate with the proper incentive in the form of a premium for attaining a set rate of output could be established, a considerably better production per day could be realized. However, as it had been noted during the time studies that the speeds of the grinders operated by the various men differed considerably, an investigation as to the effect of the machine speed upon the output per operator was made before deciding upon any set time for the work. The number of dies lapped by each operator, with the times actually consumed in the work, was plotted to scale, as illustrated in Fig. 33. This graphic depiction indicated that the machine speed had some little noticeable effect upon the output of the individual workers, as an inspection of the graphs will show. The operator of the speediest machine had the best record, it is true, but the man operating the machine with the next highest speed had very nearly the worst record. How-

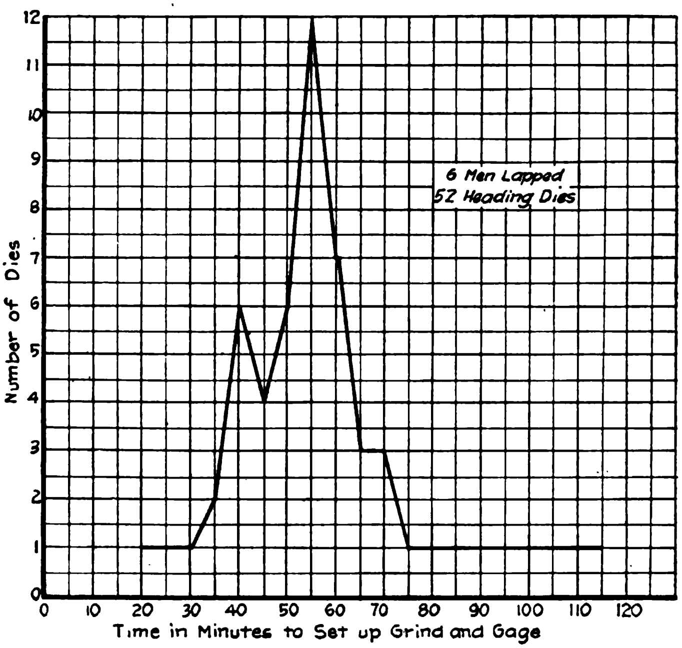


FIG. 30.—PRODUCTION CURVE—THIRD DAY

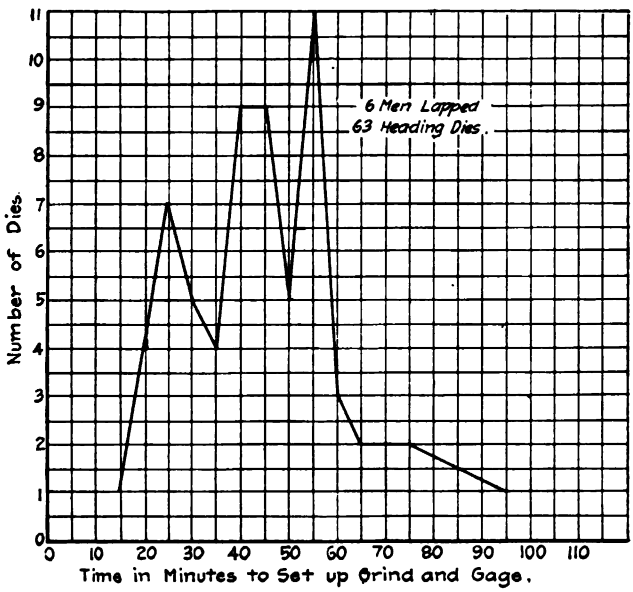


FIG. 31.—PRODUCTION CURVE—FOURTH DAY

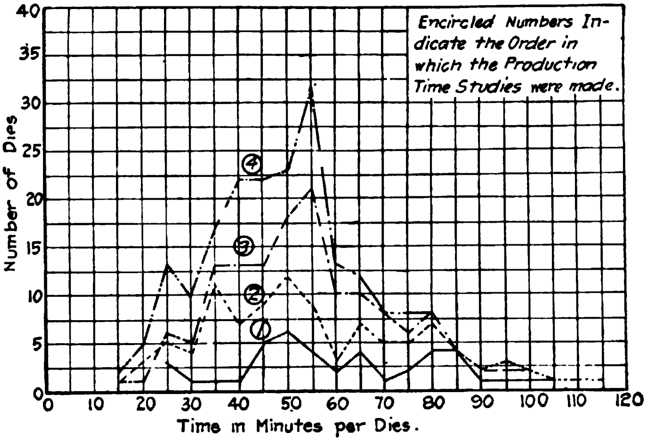


FIG. 32.—ACCUMULATIVE PRODUCTION CURVE

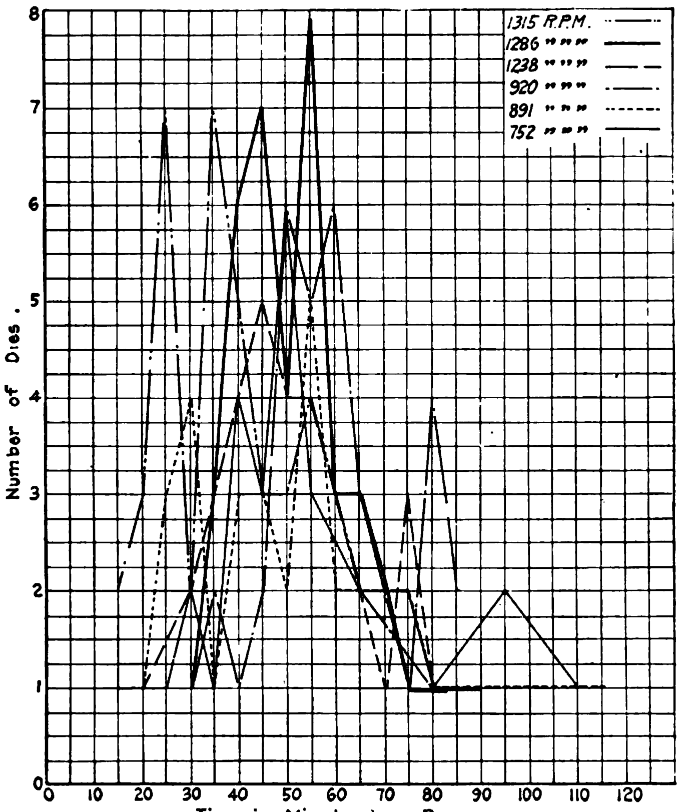


FIG. 33.—PRODUCTION CURVES PER WORKER

ever, as most of the men operating the speedier machines had good records, the showing of the operator with the second highest-speed machine was attributed to a personal factor and it was decided to bring the speeds of all machines to that of the speediest, 1,315 r.p.m. Prior to the standardization of machine speed, the great majority of the dies lapped took from 20 to

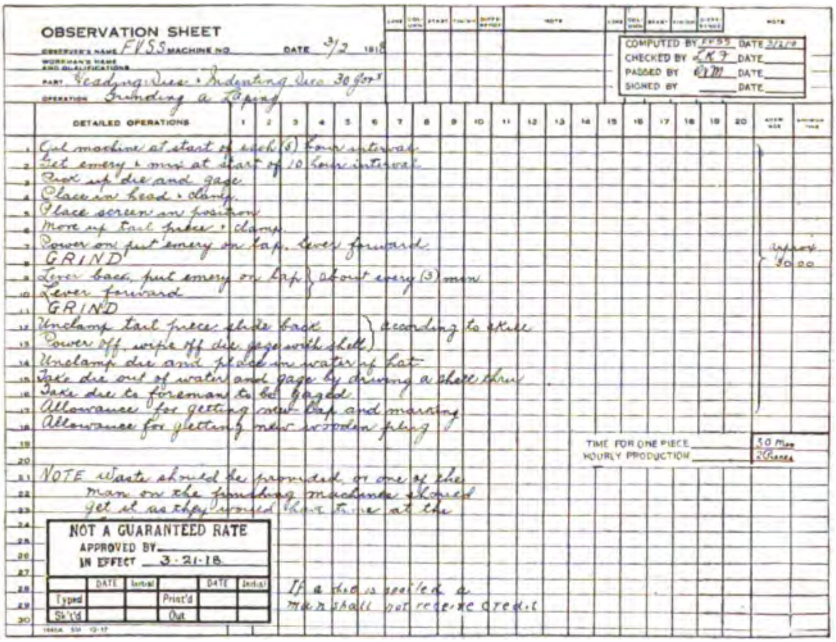


FIG. 34.—TIME-STUDY OBSERVATION SHEET—LAPPING HEADING DIES

65 minutes each, while the operator having the best record, had an average record of a die every 25 to 35 minutes.

As the conditions affecting the slower workers could be made similar to those governing the work of the operator with the best record, as by establishing the standard machine speed, the average time for lapping one heading die was placed at 30 minutes and a sequence of operations drawn up to guide the men in their work—as listed on the observation sheet, Fig. 34. Unit times for the elementary operations could not be established, on account of the variations in the work entailed, but allowances were included in the selected time for such necessary interruptions as getting and preparing new copper and wooden laps. Recommendation was also made that the waste required

should be provided the workers at their machines, or else that it should be procured at the start of the day by the men working on the finishing machines, at which time the finishers are not as busy as later in the day, when the work accumulates for finish lapping.

In order to secure output at the rate of 30 minutes per die, it was necessary to introduce a plan of reward for unusual effort on the part of the workers, set as equalling the new rate, as the department had formerly been conducted on a day work basis. It was deemed advisable to adopt a bonus plan, where the day-work pay is guaranteed the worker, so the Halsey premium plan, which had been used with success in other departments of the same factory, was selected. The plan introduced is that where the workman receives as a bonus half the pay at his regular-day rate for any time he may save in completing work for which a set-task time is fixed. The plan introduced is that the worker receives a premium for performing an operation in better than set time, in addition to his regular pay for the time actually consumed under task, consisting of full pay for one-half of the time saved in completing the task. The set time is arrived at by adding two-thirds to the selected, or task, time. Whenever the operator performs a task in the selected time, he receives as a premium pay proportional to one-third of his day rate. When the operation is performed in less than selected time, his premium is proportionately greater, or when under the set time, though in excess of the selected time, the premium is proportionately reduced. When the task is performed in the set time, or on a poorer rate, no premium is earned.

The premium rate was put into effect March 21st, and as the selected task time for lapping one die was placed at 30 minutes, the worker was allowed 50 minutes for each die. That is, the worker succeeding in maintaining an average hourly production of two dies, was paid at a rate of 40 minutes per die, though actually taking an average of 30 minutes for lapping each die.

The wisdom of placing the work on a time basis and offering a premium to the worker, should he succeed in maintaining the selected time (30 minutes) for the work, was immediately apparent, as graphically depicted in Fig. 35. Prior to March 21st, the average number of dies lapped per man per day was in the neighborhood of 10, or an hour per die, while on the first day on a premium basis, the number jumped to 14, on the second day to 15 and within three weeks the daily output had increased to 20 or more. In other words, a time study on an

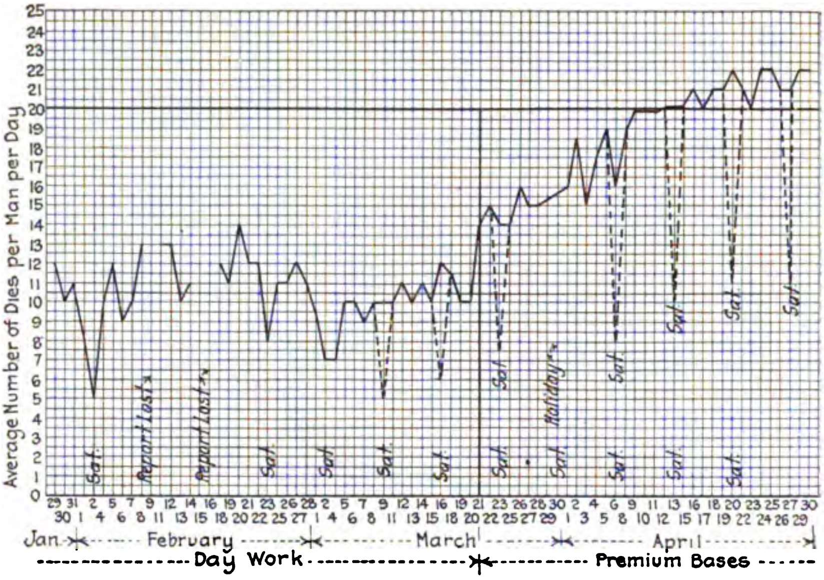


FIG. 35.—PRODUCTION BEFORE AND AFTER RATE SETTING

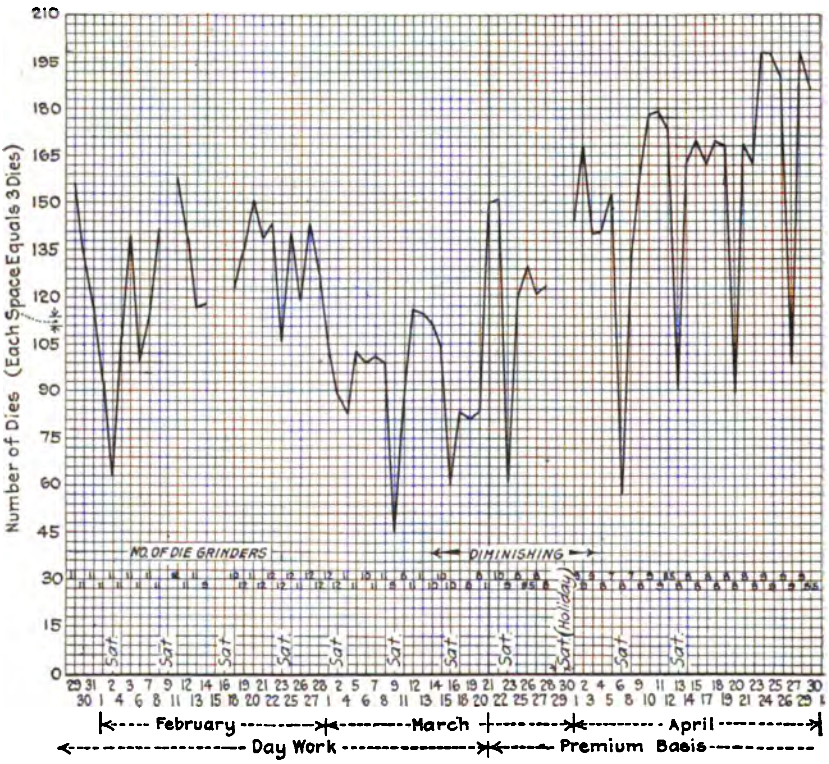


FIG. 36.—NUMBER OF LAPPERS AND PRODUCTION

operation that apparently was one so variable in nature as to prohibit arriving at an equitable rate at which the work should be done, necessitating its being conducted on a day-work basis, was placed on a premium basis and production was doubled. That is, the effect of placing the work on a plan or reward was to reduce the labor cost of lapping the heading dies by 16⅔ per cent., and the overhead by 50 per cent., while the workmen received a very substantial increase in weekly wage—approximately one-third extra.

An even more striking result of the change from day work to premium work is shown in Fig. 36. Before the introduction of the reward for application to work, eleven or twelve grinders were necessary to maintain even the number of dies which were averaged per day. Shortly after the introduction of the premium rate, the average number of dies lapped per day was increased by about a half and the number of grinders necessary for the increased production reduced to about two-thirds the number employed on day work for the lapping of but two-thirds as many heading dies.

SECTION II

THE STUDY APPLIED TO LINE OF MACHINE TOOLS

CHAPTER VII

TIME STUDIES FOR RATE SETTING ON MACHINE TOOLS

IMPORTANT as are time studies for setting rates on complete operations (Operation-time Studies), be they manual, machine or those which combine both handling and machine work, they necessitate more or less prolonged activity on the one operation. That is, for the time study to be of economic value, the operation studied must be one that will be actively conducted for a period considerably more extended than the day or two during which the analytical investigation for the best manner and rate at which to perform the work is made. Otherwise, the information so gained can only become a matter of recorded interest for possible future activity, instead of valuable data for immediate practical use.

In commercial manufacture, the same operation, it is true, is usually performed over and over again on standardized product for which a demand has been created, but there are many more operations conducted which may be repeated only occasionally. While these more special operations may not afford an opportunity for operation-time study, yet it is imperative that the operation be performed expeditiously and economically and that some definite rate be set for the task such as may be consistently attained by a diligent worker, without undue fatigue. Even in the case of a standardized operation, it is always valuable to be able to estimate the rate, even though it be subsequently checked by an operation-time study. Furthermore, improved methods and processes are much more readily arrived at if it be possible to estimate accurately in advance the time required for the altered element operations, etc.

The acquisition of data necessary for estimating accurately the time required for any piece of work calls for not only an intimate knowledge of the allowances which should be made for unavoidable delays, as presented in Chapter V, but as comprehensive familiarity with the work to be done and the capacities and peculiarities of all machines and equipment employed for the work. This knowledge must embrace not only full information concerning the actual machine work, but also con-

cerning all such incidental operations as preparing the machine for the work, placing the work in the machine and removing it. The data is secured by time studies similar to those described in preceding chapters. From the records thus obtained comprehensive elementary time tables are compiled and the tables can then be employed to set accurate rates for any operation. Important as is the securing of data for the tables and the use of the time tables in rate setting, the compiling of the tables constitutes the all-important link between observation and application. By compiling comprehensive time studies on elementary operations, data is presented in such form that by recombining the elementary operation times in varying sequences and combinations, the operations necessary to the completion of any conceivable piece of work may be outlined and a predetermined rate set for the task, with detailed instructions for its performance.

Obviously, the compilation of a comprehensive set of time tables for any industry involves a stupendous amount of work, for time studies must be made on all types of machines under diverse operating conditions, the data secured must be analyzed and rechecked until there remains no doubt as to the authenticity and reliability of the information secured. However, the records of every carefully conducted time-study are of value as data for such tables and, when properly correlated furnish not only basic information for the setting of base times and rates on specific machines, but develop facts which influence improvement in machine design, particularly as pertains to operation.

The time studies, whether on hand work, machine tools or on the operation of other industrial equipment, do not differ in procedure from the operation-time studies discussed in the preceding chapters. Nevertheless, in taking up an exposition of the compilation of elementary time tables for rate setting on machine tools, certain terms which will recur frequently may be defined to advantage.

Element or elementary operation. The smallest sub-division of the job or work that is to be studied. Example: Take up wrench; tighten nut.

Fundamental operation. A sequence of elements comprising the performance of some definite portion of a job. A single fundamental operation may apply to several different classes of work or to several different sizes and types of machine. Example: Put tool in tool post; remove tool from tool post; move head along rail, etc.

Complete operation. A division of machine work that is complete in itself. It is made up of one or more fundamental operations.

Job or work. The combination of complete operations necessary to the completion of the work in a single machine. Example: Boring a cylinder; planing a lathe bed, milling the teeth of gear.

Right hand (of a machine). That portion of the machine that is at the right of the workman as he stands in front of and facing it.

Left hand (of a machine). That portion of the machine that is at the left hand of the workman as he stands in front of and facing it.

The procedure to be followed in taking a machine time study entails the analytical division of the job into classified elementary operations and the determination by means of a stop watch of the length of time required for the performance of each one of the elements. The results secured should be carefully weighed and analyzed and in preparing instruction cards for making use of the acquired knowledge the same sequence of classified operations should be followed. In general machine shop practice the job can be divided into a sequence of elementary operations under the following heads:

1. Preparing the machine to receive the work (from normal condition).
2. Landing the work in the machine.
3. Squaring, levelling and making the work run true.
4. Clamping or otherwise securing the work in the machine.
5. Setting tools.
6. Manipulating the machine to start the cut (includes calipering and gaging).
7. Machining—that is, removing metal.
8. Manipulating the machine at the end of the cut.
9. Removing the tools.
10. Removing the clamps and securing devices.
11. Removing the work from the machine.
12. Restoring the machine to its normal condition.

In time-study work a normal condition is assumed for each machine. This normal condition is that which will enable it to accommodate, without change, the greatest number of jobs that will come to it in the regular work of the shop. For instance, in the case of a boring mill the rail will be left at a certain elevation above the table, the heads at either end of the rail and the rams set at right angles to the rail. At the con-

clusion of each job, the machine should be restored to its normal condition. The purpose of this restoring to normal condition is to facilitate the setting of tasks on the machine by giving the man who writes the instruction cards a definite starting point in laying out the work. As will become apparent later, a large percentage of the time involved in most machine work is concerned with the preparation of the machine for the work. All instruction cards and task times will be inaccurate if the machine is in any other than the normal condition when the workman commences work upon it. In taking time studies also a normal position should be assumed for the workman—that is, the position in which he would ordinarily be found at the commencement of the operation in question. Thus, in machining work on a boring mill, the workman would naturally take his place at the end of the cross-rail, and this position would be his normal position for the beginning of the immediately following operation—that is, loosening and removing clamps.

These various operations involved in manipulating the machine for the job may be more thoroughly defined as follows:

1. *Preparing the machine to receive the work.* This includes all adjustments of the machine necessary to fit it for the reception of work, such as the adjustment of chuck jaws, the removal or placing or faceplates or chucks, the adjustment of the footstock, etc., in the case of lathes; the raising of the rail, the movement of the heads, etc., in the case of planers and boring mills; and similar operations that can readily be called to mind on other machines.

2. *Landing the work in the machine.* This item includes the lifting and placing of the work in position ready for clamping or otherwise fastening in the machine by hand. Or, if the piece is too heavy to be moved by hand, the attaching of slings, and hoisting by means of block and chain hoist, pneumatic hoist or crane, the movement or traverse or the work to the machine, the landing of it in position in the machine and the removal of the slings.

3. *Squaring, levelling and making the work run true.* This item includes all operations necessary to make the surface that is to be machined conform approximately to tne path of the cutting tool.

Squaring involves the operations necessary to locate the principal edge of the work parallel to the edge of the table or to the path of the cutting tool where one or the other has a

reciprocating motion. This operation is necessary principally in connection with planers, shapers and slotters.

Levelling involves those operations necessary to bring the working surface parallel to the platen, or table, on which the work is supported. Work is levelled on the tables of planers, boring mills, drilling machines, shapers, etc. Although, using the term in its strict sense, work clamped to the faceplate of a lathe is not levelled, nevertheless the operations involved in locating the working surface parallel to the faceplate are the same as when the work is clamped to a horizontal surface, and so such operations in lathe work are properly classified as levelling.

Making work run true involves those operations required to make work carried on centers, or supported on a rotating surface as a lathe faceplate or boring-mill table, assume the same axis of rotation as that of the machine itself.

4. *Clamping or otherwise securing the work in the machine.* This item includes the tightening of chuck jaws on the work, placing clamps and blocks and tightening the bolts and nuts that hold them on the work, tightening vise jaws, and setting and making firm all attachments that hold the work in position for the cutting operations.

5. *Setting tools.* This item includes placing and tightening all cutting tools in the tool post, or tool block and making them ready for work. It does not, however, include the manipulation of the machine to bring the tool in proper position with relation to the work to begin removing metal.

6. *Manipulating the machine to start the cut.* This item involves all machine movements, including those necessary to bring the cutting tool into its proper relation to the work, and the preliminary operations of the machine necessary to turn short lengths on cylindrical work, and so obtain the space necessary for calipering to ascertain whether or not the tool is in the correct position. It also comprises the starting of the actual machining operation by throwing in the feed mechanism at the beginning of the cut, and releasing it at its completion.

7. *Machining.* This item involves only the removal of metal, and has little or no relation to the time involved in machine movements.

8. *Manipulating the machine at the end of the cut.* This item includes the fundamental operations necessary to disengage the cutting tool from the work and to bring it to a position where it can be removed or reset for another cut. In general it is the reverse of item 6.

9. *Removing the tools.* This item includes the elements required to loosen the devices holding the tool in place and to remove it to the tool stand. In general it is the reverse of item 5.

10. *Removing the clamps and securing devices.* In general this item is the reverse of item 4, except that the elements are performed in reverse order.

11. *Removing the work from the machine.* The items involved here are the same as those involved in item 2, excepting that they are performed in the reverse order.

12. *Restoring the machine to its normal condition.* The operations comprised in this item are practically identical with those comprising item 1, but in addition it includes the operation of cleaning the entire machine.

Time studies in which the various elements are classified as above permit of the widest use. For instance: The same studies on clamping may be applied to several different types of machines. Work may be held with U-clamps on the platen of the planer, on platen or table of the boring mill, drilling machine or shaper. It makes no difference what machine is involved, so long as the character of the work to be clamped and the relative conditions are the same. The time for clamping should be uniform.

Another example is calipering. The time required to caliper a piece of work depends but little upon the machine in which the work is placed, but does depend very largely upon the size of the work itself. Studies on calipering in one class of machine are equally applicable to other types.

Again, in hoisting and landing, it makes but little difference whether the work is landed in the machine on centers, or lowered in position on the table. The weight and distance a piece is to be moved will make quite a difference, and time studies on hoisting and landing, therefore, are classified first with respect to the method of handling—whether by hand, chain, pneumatic, or electric hoist, or crane—second, with respect to weight and third, with respect to the distance moved. Classified in this manner the different groups of time studies can be combined one with another to fix the time required for practically every class of work. There will, of course, be necessary additional time studies peculiar to the machine in which the work is placed. That is, in addition to studies of hoisting, landing, calipering, etc., applicable to all classes of work, there must be studies in machine manipulation for the different machine tools, such as

lathes, planers, millers, shapers, drilling machines, etc., and studies of tool setting for these various machines.

A clearer comprehension of the approved procedure in taking machine time studies and of the details to be noted can doubtless be formed from a brief enumeration of the investigations and combinations of elementary operations made for the Gisholt boring mills. The procedure entailed first dividing the operations on Gisholt boring mills into their fundamental operations such as: 1. Preparation of the machine, including oiling and certain machine manipulation such as raising and lowering the rail, swiveling the ram, changing position of the tool post, etc. 2. Manipulation of the machine, including rapid travel of the head and rail, revolving of the turret, operating speed and speed gears, etc. 3. Hoisting and landing work on the machine. 4. Clamping work. 5. Setting and starting cuts which include some machine manipulation already stated in 2, and some machine elements not stated elsewhere. The studies were made on a series of machines ranging from 30 to 84 inches in size, and all of the operations outlined were studied on each machine.

Each of the fundamental operations comprised in the foregoing subdivisions was analyzed into its most elementary motions and the sequence of operations from start to finish as revealed by this analysis was tabulated. An example of this is a study made on the turning of chuck jaws end for end. The elements are as follows:

1. Obtain wrench from tool stand.
2. Loosen two $\frac{5}{8}$-inch setscrews in first jaw.
3. Remove jaw from slot.
4. Clean slot.
5. Turn jaw end for end and re-enter it in slot.
6. Set jaw to line on table.
7. Tighten two $\frac{5}{8}$-inch setscrews in jaw.
8. Turn table 120 degrees.
9. Loosen two $\frac{5}{8}$-inch setscrews on second jaw.
10. Remove jaw from slot.
11. Clean slot.
12. Turn jaw end for end and re-enter it in slot.
13. Set jaw to line on table.
14. Tighten two $\frac{5}{8}$-inch setscrews in jaw.
15. Move table 120 degrees.
16. Loosen two $\frac{5}{8}$-inch setscrews in third jaw.
17. Remove jaw from slot.
18. Clean slot.

19. Turn jaw end for end and re-enter it in slot.
20. Set jaw to line on table.
21. Tighten two ⅝-inch setscrews in jaw.
22. Return wrench to tool stand.

These various elements may then by combined one with the other to give a complete progressive tabulation of the operations considered as fundamental for boring mills of the Gisholt type.

1. *Preparation.* Oil, raise and lower rail, swivel head to angle, remove from and replace tool post or bar in ram, raise or lower tool post in ram, set chuck jaws on table, remove chuck jaws from table.

2. *Landing.* On centers, by hand; on centers, by hoist; in chuck, vertical, by hand; in chuck, vertical, by hoist; in chuck, horizontal, by hand; in chuck, horizontal, by hoist; on table or platen, by hand; on table or platen, by hoist; on table in V-blocks, by hand; on table in V-blocks, by hoist; in vise, by hand; in vise, by hoist; on arbor, by hand; on arbor, by hoist.

3. *Squaring, levelling and making work run true.* In chuck, in chuck and steady rest, on centers, on platen on faceplate.

4. *Clamping.* Clamping work in chuck jaws, clamping with U-clamps, clamping with goose-neck clamps, removing work from chuck jaws, removing U-clamps, removing goose-neck clamps.

5. *Setting tools in post.* Set tools in tool post in right-hand head for cut on outside diameter: (a) Round-nose roughing tool, (b) square finishing tool. Set tools in tool post in right-hand head for cut in face: (a) Round-nose roughing tool, (b) square-nose finishing tool. Set tool in tool post in left-hand head, tools set for cut on outside diameter: (a) Round-nose roughing tool, (b) square-nose finishing tool. Set tools in tool post in left-hand head, tools set for cut on face: (a) Round-nose roughing tool, (b) square-nose finishing tool.

The following are common to many types of machines, and must be used in preparing instruction cards for boring mills, planers, shapers, drilling machines, etc.

6. *Manipulation.* Change position of head, start motor, stop motor, start table, stop table, change feed gears, change speed gears, ratchet head back.

This classification and standardization of fundamental operation paves the way for an effective analysis of the data secured from time studies made on the operation of the Gisholt boring mills as well as the compilation of accurate time tables.

CHAPTER VIII

PREPARING BORING MILLS TO RECEIVE WORK

THE taking of time studies on the preparation of Gisholt boring mills for any specific job, as well as similar investigations for elementary time tables on other fundamental operations, differs in no way from the methods already presented for operation-time studies. The data recorded from the stop-watch readings, to hundredths of a minute, should advisably be plotted to large scale on cross-section paper and smooth curves drawn to depict the trend of relationship in the time consumed in the performance of the various elementary operations for the different sizes of boring mills. From such curves, the unit times entered in the time tables can be accurately ascertained to as many decimal points as may seem advisable. Ordinarily values carried to three decimal points for the elementary operations and two for the total fundamental operations are sufficiently accurate for all practical purposes. This method of securing time-table data is more reliable than dependence upon values obtained directly from the time studies, as the chances of errors in reading the watch and the effect of unusual conditions, delays, etc., are discounted to a considerable degree, if not entirely eliminated. Furthermore, if a sufficient number of machines of different sizes and a suitable number of studies are made to establish conclusively the trend of the relationship curve, time values for machines intermediate in size to those actually investigated can be accurately determined.

The data pertaining to the operations necessary to prepare Gisholt boring mills, 30, 36, 42, 60 and 84-inch classes,* and presented in the following tables, are obtained from trend curves established by numerous comprehensive time studies made in the approved manner on the various machines. It is assumed that each machine is in its normal condition at the time work is to commence, and that the work is of such character as to necessitate a change from this condition. The

* Classes of Gisholt boring mills embrace other sizes than those spencifically mentioned, but machines which are of about the same size are of the same general characteristics.

operations comprised in the preparation and the tables of unit times relating to them are as follows:

PREPARATION OF MACHINE TO RECEIVE WORK

Fundamental Operations	*Table*
Oil machine	1
Move rail by power	2, 2*A*
Swivel head to angle	3, 3*A*, 3*B*
Remove and replace tool post or bar	4
Change position of tool post	5
Set chuck jaws to line	6
Remove chuck jaws from table	7
Reverse chuck jaws on table	8
Move chuck jaws in or out to line	9

The normal condition of the machine must be determined separately for each shop. There also must be provided a tool stand, on which tools, equipment, drawings, instruction cards, etc., are kept. The tool stand should be placed about three feet from the machine and in such a position that the workmen can reach any article on it with a minimum of effort.

In using the tables herewith, relative to preparing the machine for the work, a survey of the job is first made to determine what changes from the normal condition of the machine are necessary, and the operations necessary to make these changes are listed in the instruction card in the order in which they take place. The time required for each operation is taken from the appropriate table and set opposite that item in the instruction card.

Such deductions as the conditions may require are made from the total times as given in the tables, and the net times only are entered on the card. For instance, if the preparation of the machine involves both the raising of the rail and the swiveling of the head, the workman should procure the necessary wrenches for both operations in a single trip to the tool stand, and this fact should be so stated on the instruction card. The time allowed for swiveling the head then would be the total time given in the table, less the time for returning the wrenches used for that operation. These would be returned with the wrenches used in raising the rail, when that operation is completed. The time allowed for raising the rail would be the total time given, less the time for procuring the wrenches. The detailed operations are given in the tables partly to enable such modifications to be made, but mainly to establish a standard practice based on the methods of the best workmen and on careful studies and correction of these methods.

Oiling, the first of the fundamental operations for preparing the boring mill for work, should be attended to the first thing

TABLE 1

OIL MACHINE

GISHOLT BORING MILLS

Details of operation	Oil can No.	30	36	42	60	84
		Size of Machine in Inches				
1. Carry cans to right side of machine	....	0.09	0.09	0.09	0.10	0.11
2. Fill holes in feed box	1	*(24) 1.44	*(24) 1.44	*(25) 1.50	*(28) 1.68	*(32) 1.92
3. Fill reservoir of lower feed box	2	0.27	0.28	0.30	0.35	0.41
4. Fill reservoir of rapid-travel mechanism	2	....	0.16	0.16	0.17	0.18
5. Fill reservoir on upper rail bracket	2	0.51	0.52	0.53	0.56	0.63
6. Fill six-pipe sight-feed oiler	2	0.70	0.70	0.70	0.70	0.70
7. Fill reservoir	2	0.16	0.16	....	....	....
8. Fill reservoir for lubricating back gears	2	....	....	0.18	0.18	0.18
9. Fill 3-ounce oil cup	2	....	....	0.30	0.30	0.30
10. Pick up cans, walk around motor	....	....	....	0.06	0.09	0.10
11. Fill reservoirs on pinion shaft	2	....	....	†(3) 1.20	†(6) 2.40	†(4) 1.60
12. Fill cup on shaft under motor	2	....	....	1.80	1.80	1.80
13. Fill 3-ounce oil cups	2	....	....	†(2) 0.60	†(3) 0.90	†(3) 0.90
14. Pick up cans, walk to left side of machine	....	....	....	0.07	0.08	0.09
15. Fill reservoirs of lower feed box	2	....	....	0.30	0.35	0.41
16. Fill reservoir of rapid travel	2	....	....	0.16	0.17	0.18
17. Fill reservoir on upper-rail bracket	2	....	....	0.53	0.56	0.63
18. Fill oil holes in feed box	1	....	....	*(25) 1.50	*(28) 1.68	*(32) 1.92
19. Climb on table	....	....	....	0.15	0.17	0.20
20. Fill oil holes	1	....	....	*(6) 0.30	*(9) 0.54	*(9) 0.54
21. Descend from table	....	....	....	0.06	0.08	0.11
22. Remove cars to stand	....	0.08	0.08	0.09	0.09	0.10
23. Clean hands with waste	....	0.20	0.20	0.20	0.20	0.20
Total time for oiling machine	....	3.50	3.60	11.00	13.00	13.50

* Number of oil holes. † Number of oil cups.

each morning if the machine is in constant use or, if used only intermittently, the machine should be oiled before beginning the first job of the day. Preferably, oiling should not be considered part of the actual preparation time of a job, but should be cared for by a separate time card issued to that operation only. To oil the larger Gisholt boring mills, some twenty-three distinct elementary operations are necessary, as itemized in Table I, though in the case of the 30 and 36-inch mills fewer operations are required on account of the greater simplicity of machine construction for the smaller tools. Table I also lists the unit times for the various elementary operations, which, when totaled, give, as the necessary time allowances for oiling the mills from 30 to 84 inches in size, 3.45, 3.63, 10.80, 13.15 and 13.21 minutes, respectively.

The first operation chargeable to the actual preparation of the machine for work is then that of moving the rail by power. This task naturally divides itself into three parts: 1. Preparation, involving the procuring of tools, loosening clamping nuts, engaging of the necessary levers, etc.; 2. actual movement of the rail; 3. clamping the rail in its new position and returning

the tools to the stool stand. The details of (1) and (3) are given in Table 2, and the time for actually moving the rail a given distance, together with the total time for the complete operation, is given in Table 2*A*. Ordinarily, in the preparation of instruction cards only the totals in Table 2*A* would be used. For instance, this particular item on the card for, say a 42-inch mill would read, "Move rail 10 inches... 1.734 minutes." This operation can be performed only on 42-inch and larger machines. The rail is in a fixed position on the smaller machine.

On certain machines the number of clamping nuts on the right-and-left-hand housings differs, thus accounting for the

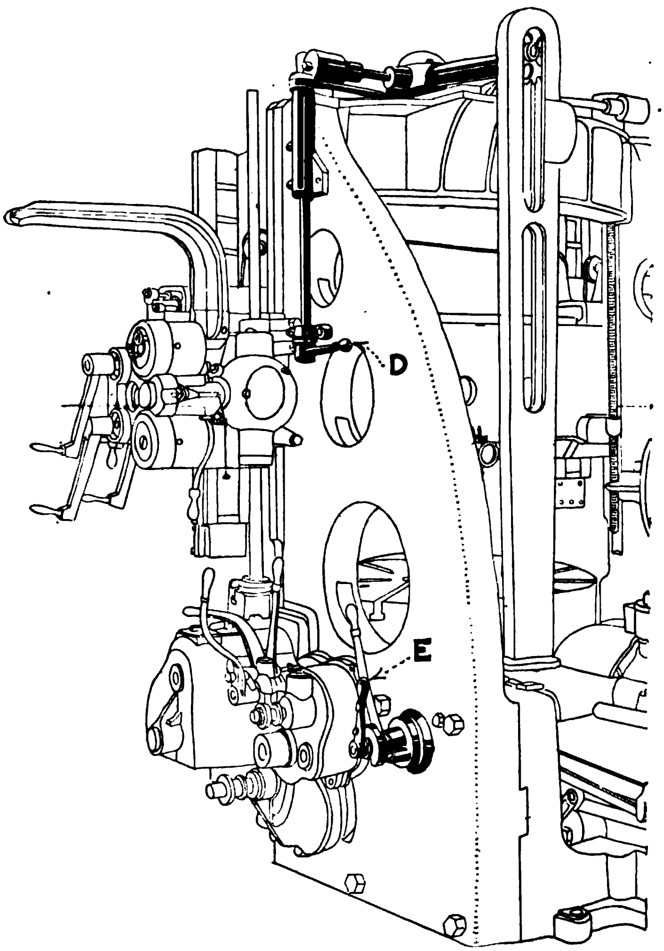


FIG. 37.—OPERATING MECHANISM FOR MOVING RAIL, 42, 60 AND 84-INCH GISHOLT BORING MILLS

difference in time for loosening or tightening nuts on the opposite sides of the machine (Table 2). The chain drive transmitting power to the elevating screws of the rail is set in motion by throwing the lever *D*, shown in Fig. 26. The clutch connecting the rail to the elevating screws is meshed by the lever *E*, and the rail will continue to move as long as this clutch is in mesh. When the rail has reached the desired elevation, the lever *E* is released and the chain drive disengaged by means of the lever *D*.

In raising the rail, it can be brought to the desired height and stopped. In lowering, however, it should be lowered below the desired point and reraised to the correct elevation in order to take up the lost motion in the elevating screws and nuts. While this will actually make a slight difference in the time for raising or lowering the rail through a given distance, the difference is so small that for all practical purposes the time for raising or lowering may be considered the same.

TABLE 2

MOVING RAIL BY POWER

GISHOLT BORING MILLS

Details of operation	Size of Machine, Inches		
	42	60	84
Preparation for moving rail	Time in minutes		
1. Get wrench from tool stand	0.0425	0.055	0.070
2. Walk to left side of machine	0.0700	0.080	0.100
3. Loosen clamping screws	0.1700	0.360	0.285
4. Walk to right side of machine	0.0920	0.105	0.125
5. Loosen clamping screws	0.1700	0.270	0.285
6. Lay down wrench	0.0200	0.020	0.020
7. Engage clutch to operate chain	0.0500	0.050	0.050
8. Engage clutch to move rail	0.0400	0.040	0.040
Total preparation for moving	**0.65**	**0.98**	**0.98**
9. Move rail		....See	Table 2*A*
10. Disengage elevating-chain clutch	0.040	0.040	0.040
11. Pick up wrench	0.050	0.056	0.065
12. Tighten clamping screws, right side	0.255	0.405	0.427
13. Walk to left side of machine	0.092	0.105	0.125
14. Tighten clamping screws, left side	0.255	0.540	0.427
15. Remove wrench to tool stand	0.090	0.100	0.120
16. Return to front of machine	0.040	0.055	0.070
Total time for clamping rail after moving	**0.82**	**1.30**	**1.27**

Tools required: Open-end wrench.
Starting position of operator: In front of machine.

TABLE 2A

TOTAL TIME FOR MOVING RAIL

GISHOLT BORING MILLS

Distance through which rail is moved	5 in.	10 in.	15 in.	20 in.	25 in.	30 in.
	42-inch Boring Mill Time in Minutes					
1. Prepare to move rail (Table 2)	0.6545	0.5645	0.6545	0.6545		
2. Move rail	0.1740	0.3480	0.5220	0.6960		
3. Clamp rail (Table 2)	0.8220	0.8220	0.8220	0.8220		
Total time for moving rail	1.65	1.73	2.00	2.17		
	60-Inch Boring Mill					
1. Prepare to move rail (Table 1)	0.980	0.980	0.980	0.980		
2. Move rail	0.694	1.390	2.083	2.780		
3. Clamp rail (Table 1)	1.301	1.301	1.301	1.301		
Total time for moving rail	2.98	3.67	4.36	5.06		
	84-Inch Boring Mill					
1. Prepare to move rail (Table 1)	0.975	0.975	0.975	0.975	0.975	0.975
2. Move rail	0.800	1.600	2.400	3.200	4.000	4.800
3. Clamp rail (Table 1)	1.274	1.274	1.274	1.274	1.274	1.274
Total time for moving rail	3.05	3.85	4.65	5.45	6.25	7.05

To swivel the head of the mill to the required angle, the next operation in preparing the machine for work, entails somewhat different operations for the various sizes of machines. In the case of 30 and 36-inch Gisholt boring mills, the head is swiveled by hand to approximately the desired angle and clamped losely in position. Then, by tapping the head one way or the other with a lead hammer or mallet, it is adjusted accurately and the clamping nut screwed home. On 42-inch mills and larger the head is swiveled by means of a worm operated by an open end wrench and can, therefore, be moved exactly to the desired angle.

The complete operation of swiveling the head divides into the fundamental operations of loosening, swiveling and clamping. The unit times for loosening and clamping are given in

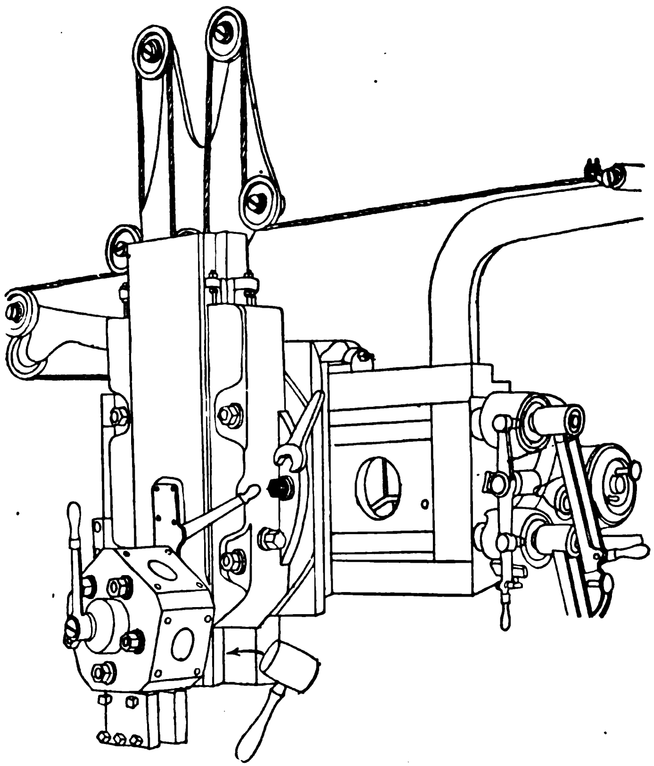


FIG. 38.—SWIVEL HEAD—30 AND 36-INCH GISHOLT BORING MILLS

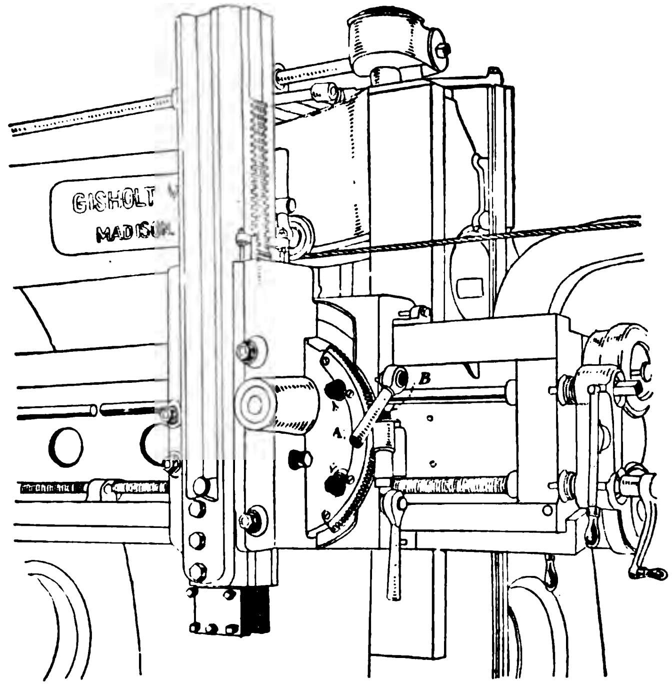


FIG. 39.—SWIVEL HEAD—42, 60 AND 84-INCH GISHOLT BORING MILLS

Table 3, those for swiveling and for the complete operation in Tables 3*A* and 3*B* for the smaller and larger sizes of mills, respectively.

TABLE 3

LOOSEN AND CLAMP HEAD

GISHOLT BORING MILLS

Details of operation	Size of Machine Inches 30	Size of Machine Inches 36
	Time in minutes	
Loosen head		
1. Obtain wrench and lead hammer from tool stand	0.055	0.06
2. Loosen hexagon clamping nuts	0.280	0.42
3. Lay wrench on table of machine	0.020	0.02
Total time for loosening head	0.36	0.50
4. Swivel head to or from zero	See Table 3*A*	
Clamp head		
5. Exchange lead hammer for wrench	0.03	0.03
6. Tighten firmly nuts on right side of head	0.14	0.21
7. Tighten firmly nuts on left side of head	0.20	0.30
8. Remove wrench and hammer to tool stand	0.055	0.06
Total clamping time	0.43	0.60

	42 Inch	60 Inch	84 Inch
1. Obtain two wrenches from stand	0.06	0.07	0.09
2. Loosen clamping nuts	0.28	0.28	0.42
3. Lay wrench on table	0.02	0.02	0.02
4. Pick up worm-operating wrench	0.03	0.03	0.03
Total time to loosen head	0.39	0.40	0.56
5. Swivel head to or from zero	See Table 3*B*.		
6. Lay down worm-operating wrench	0.02	0.02	0.02
7. Pick up clamping wrench	0.03	0.03	0.03
8. Tighten clamping nuts	0.40	0.40	0.60
9. Remove wrenches to tool stand	0.06	0.07	0.09
Total time to clamp head	0.51	0.52	0.74

TABLE 3*A*

Total Time to Loosen and Swivel Head and Clamp Swivel Head to Angle
Gisholt Boring Mills

Degrees of swivel	5	10	15	20	25	30
	30-inch Machine—Time in Minutes					
Loosen head (Table 3*A*)	.355	.355	.355	.355	.355	.355
Swivel head	.19	.21	.225	.24	.25	.27
Clamp head (Table 3*A*)	.425	.425	.425	.425	.425	.425
Total time for swiveling head	0.97	0.99	1.01	1.02	1.03	1.05
	36-inch Machine					
Loosen head (Table 3*A*)	.50	.50	.50	.50	.50	.50
Swivel head	.20	.22	.23	.25	.26	.28
Clamp head (Table 3*A*	.60	.60	.60	.60	.60	.60
Total time for swiveling head	1.30	1.32	1.33	1.35	1.36	1.38

Tools required: Lead hammer or mallet, clamping wrench.
Normal position of workman: In front of machine.
Normal condition of machine: Head at right angles to rail.

TABLE 3*B*

Total Time to Loosen Swivel Head and Clamp
Gisholt Boring Mills

Degrees	5	10	15	20	25	30	35	40	45
	42-Inch Machine								
Loosen head (Table 3*A*)	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Swivel head	0.37	0.45	0.54	0.64	0.75	0.86	0.97	1.09	1.22
Clamp head (Table 3*A*)	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Total time for swiveling head	1.27	1.35	1.44	1.54	1.65	1.76	1.87	1.99	2.12
	60-Inch Machine								
Loosen head (Table 3*A*)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Swivel head	0.43	0.51	0.61	0.71	0.82	0.93	1.05	1.17	1.30
Clamp head (Table 3*A*)	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Total time for swiveling head	1.35	1.43	1.53	1.63	1.74	1.85	1.97	2.09	2.22
	84-Inch Machine								
Loosen head (Table 3*A*	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Swivel head	0.48	0.57	0.67	0.76	0.89	1.00	1.12	1.25	1.40
Clamp head (Table 3*A*)	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Total time for swiveling head	1.78	1.87	1.97	2.06	2.19	2.30	2.42	2.55	2.70

The removing and replacing of the tool post or bar in Gisholt boring mills also entail somewhat different procedure in various sizes of mills. The tool posts in the larger sizes may be carried either in the ram or the turret head on the ram, but in the smaller sizes—30 and 36-inch mills—are always placed in the turret heads.

The tool post or bar is removed from the turret head by loosening a single hexagon clamping bolt in the head, which allows the bar or post to drop out. The workman, while loosening the clamping bolt, holds the bar or post with his free hand to

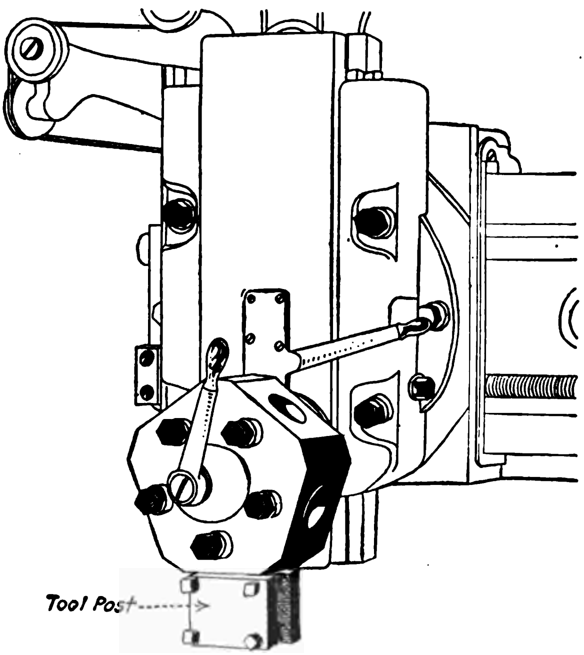


FIG. 40.—OPERATION TO REMOVE TOOL POST—30 TO 84-INCH GISHOLT BORING MILLS

prevent it from falling to the table. After loosening the bolt, the bar or post is grasped with both hands, lifted out of the head and removed to a convenient position on the floor alongside the tool stand. The table assumes that the bar or post that is to replace the one removed is at hand on the floor or tool stand and that it is procured and carried to the machine on the return trip, after disposing of the first post or bar. It is placed in the turret head and held in position with one hand, while with a wrench in his free hand the workman tightens the clamping nut.

The process of removing and replacing the tool post or bar in the ram is the same as removing or replacing it in the turret heads, except that there are three clamping bolts to be manipulated and a locking pin to be pulled out. The purpose of this pin is to prevent the bar or post from falling to the table when the clamping bolts are loosened. The workman holds the bar with his free hand while he releases the locking pin and then uses both hands to remove the bar.

The time table for all elementary operations involved in removing and replacing the tool post or bar in the ram or turret head of Gisholt boring mills—30 to 84-inch machines inclusive—is given as Table 4.

TABLE 4

REMOVE AND REPLACE TOOL POST OR BAR

GISHOLT BORING MILLS

Details of operations	Size of Machine, Inches					
	30	36	42	42	60	84
	Time in Minutes					
1. Obtain wrench from tool stand, walk to left of side of machine	0.09	0.10	0.10	0.10	0.13	0.16
2. Loosen hexagon clamping bolts	0.07	0.07	0.07	0.12	0.17	0.20
3. Lay wrench on table	0.02	0.02	0.02	0.02	0.02	0.02
4. Remove post or bar from turret	0.03	0.03	0.03			
5. Pull pin and remove post or bar from ram	......	......	......	0.06	0.09	0.12
6. Remove post or bar to floor	0.05	0.05	0.07	0.07	0.08	0.09
7. Carry bar or post to machine	0.08	0.08	0.09	0.09	0.12	0.14
8. Put bar or post in turret	0.04	0.04	0.04			
9. Put bar or post in ram	......	......	......	0.15	0.17	0.20
10. Pick up wrench	0.02	0.02	0.02	0.02	0.02	0.02
11. Tighten hexagon clamping bolts	0.12	0.12	0.12	0.22	0.26	0.29
12. Return wrench to tool stand	0.07	0.07	0.08	0.08	0.09	0.11
Total time to remove and replace tool post or bar	0.59	0.60	0.64	0.93	1.15	1.35

Tool required: Open-end wrench.
Normal position of workman: In front of machine.
Normal condition of machine: Tool post or bar in head or ram.

The position of the tool post as regards its distance from the base of the ram—in 42, 60 and 84-inch mills—entails another fundamental operation necessary to prepare the larger Gisholt boring mills for the reception of work—*i. e.*, raising or lowering the tool post in the ram. The distance of tool post from the base of the ram may be varied by locating the locking pin in

any one of the three slots provided in the tool-post shank. To change the position of the tool post, the three clamping bolts are loosened, and the locking pin is pulled out. The workman, meanwhile, grasps the tool post with his free hand and raises or lowers it to the desired position and releases the pin. The clamping bolts are then tightened. The elementary operations required for raising or lowering the tool post in the ram, together with the unit times for all acts, are given in Table 5.

TABLE 5

RAISE OR LOWER TOOL POST IN RAM

GISHOLT BORING MILLS

Details of operation	Raise Post			Lower Post		
	Size of Machine Inches			Size of Machine Inches		
	42	60	84	42	60	84
	Time in Minutes					
1. Obtain wrench from tool stand, walk to left side of machine	0.09	0.09	0.10	0.09	0.09	0.10
2. Loosen hexagon clamping bolt	0.12	0.17	0.20	0.12	0.17	0.20
3. Lay wrench on table	0.02	0.02	0.02	0.02	0.02	0.02
4. Pull pin, raise post	0.04	0.05	0.05			
5. Pull pin, lower post	......	......	......	0.08	0.09	0.09
6. Pick up wrench	0.02	0.02	0.02	0.02	0.02	0.02
7. Tighten clamp in bolts	0.22	0.26	0.29	0.22	0.26	0.29
8. Remove wrench to stand	0.08	0.09	0.11	0.08	0.09	0.11
Total time to raise post	0.59	0.70	0.79			
Total time to lower post	......	......	......	0.63	0.74	0.83

Tool required: Open-end wrench.
Normal position of workman: In front of machine.

Preparation for the accommodation of the work on the table of a boring mill obviously constitutes an important preliminary step in the preparation of the machine to receive work, and one which quite naturally calls for detailed study and comprehensive instruction cards if it is to be performed effectively and expeditiously. There are several common methods of holding the work to boring-mill tables—by means of chuck jaws fitted to the slots in the table, clamping it to parallels on the table, setting it in drivers, or by clamping it flat on the table.

Gisholt boring mills up to and including 42-inch have a table consisting of a three-jaw scroll chuck (Fig. 31), the jaws having

both independent and universal movements. Machines larger than 42-inch have four detachable independent chuck jaws mounted on bases held to the table by means of four T-slot bolts in parallel T-slots on the table (Fig. 32). Each jaw is moved with reference to its base by a screw operated by a socket wrench, as at *A* in Fig. 31. The assumption is made that the T-slot bolts are kept in the holes in the base.

The jaws of the three-jaw chucks are set to that line on the table which most nearly corresponds to the diameter of the

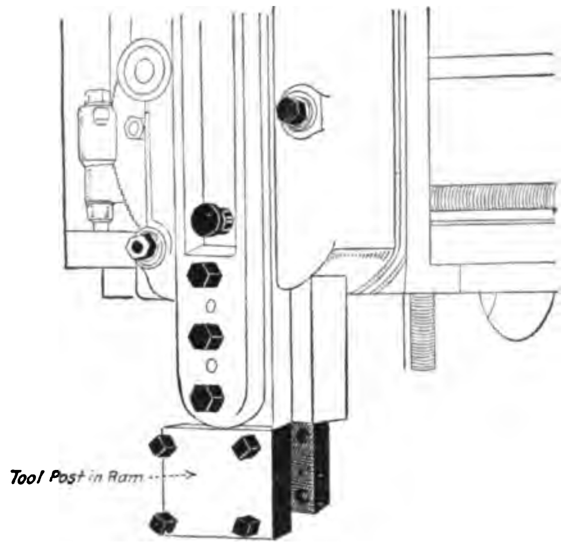


FIG. 41.—OPERATION TO LOWER TOOL POST—42, 60 AND 84-INCH GISHOLT BORING MILLS

work. They are then caused to grip the work by means of the scroll movement. See *B*, Fig. 2. The base of the independent jaw for machines larger than 42-inches is placed with its outer edge flush with the edge of the table, and the jaw is moved backward and forward in the base by means of the screw until it attains its approximate desired position with reference to the base. The base is then moved forward on the table to the line most nearly corresponding to the diameter of the work and is clamped down to the table. The operations are repeated for the second jaw before moving the table. The final adjustment of the jaws is made independently after the work is in place.

When reversing the chuck jaws on the table, as is necessary

for certain classes of work, the clamping bolts at *C* (Fig. 32), are loosened, the jaws removed from the table, turned end for end and entered in the table slots. From this point the process is the same as for setting the jaws for the first time. In the case of independent jaws for machines larger than 42-inch, adjust-

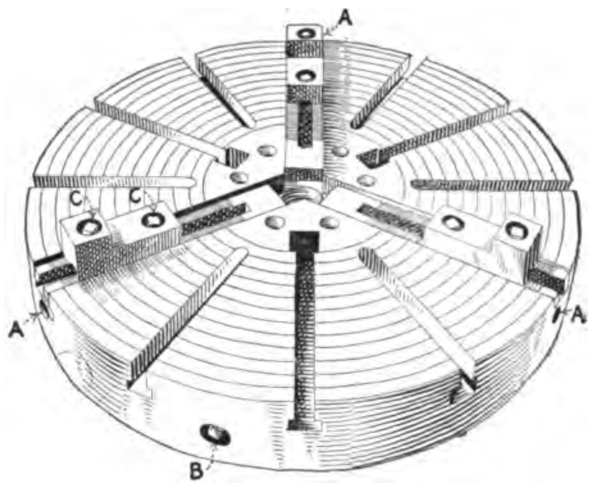


FIG. 42.—THREE-JAW CHUCK FOR BORING MILL

ment of the jaw is, as above, made with the base flush with the edge of the table.

In moving the chuck jaws on the table without reversing them it is necessary in the case of the jaws having bases, first to remove the base of the jaw until its edge is flush with the edge of the table and then to adjust the jaw to the size of the

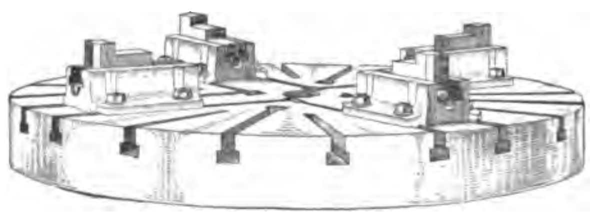


FIG. 43.—FOUR-JAW CHUCK FOR BORING MILL

piece, after which the base and jaw are moved forward to the desired location.

The time tables giving the elementary operations involved and the unit times for setting the chuck jaws to line, removing

the chuck jaws from the boring-mill table, reversing the jaws and moving them in or out as may be required, are given as Tables 6, 7, 8 and 9. The acts entailed in the operations on the three-jaw chucks differ in certain respects from those required for four-jaw chucks, it will be noted, on account of the difference in mechanical construction of the two types. However, in either case, the elementary operations listed and the unit times presented are secured from exhaustive and comprehensive time studies conducted in the sequences given and constitute authentic records of the most effective procedure in each case.

TABLE 6

SET CHUCK JAWS TO LINE

GISHOLT BORING MILLS

Details of operation	Size of Machine, Inches		
	30	36	42
	Time in Minutes		
1. Obtain rule, measure diameter of piece	0.120	0.120	0.120
2. Obtain chuck wrench from stand	0.035	0.040	0.045
3. Pick up chuck jaw	0.050	0.060	0.070
4. Insert jaw in table slot; move jaw to line	0.087	0.093	0.100
5. Tighten two screws in jaw	0.210	0.220	0.230
6. Turn table 120 degrees	0.090	0.100	0.120
7. Repeat items 3, 4 and 5	0.347	0.373	0.400
8. Turn table 120 degrees	0.090	0.100	0.120
9. Repeat items 3, 4, and 5	0.347	0.373	0.400
10. Remove wrench to stand	0.035	0.040	0.045
Total time for setting three chuck jaws	1.41	1. 52	1.65

Details of operation	Size of Macine Inches	
	60	84
	Time in Minutes	
1. Obtain rule, measure diameter of piece	0.150	
2. Obtain chuck wrench from stand	0.055	
3. Pick up chuck jaw from stand	0.110	
4. Enter slot bolt in base into table slot, on the edge flush with table	0.120	
5. Screw jaws in base to suit diameter of work	0.270	
6. Move jaw base up to line	0.160	
7. Tighten 4 [illegible]-inch clamp bolts	0.440	
8. Repeat items 3 to 7 inclusive	1.100	
9. Turn table 180 degrees	0.180	
10. Repeat twice items 3 to 7 inclusive	2.200	
11. Remove chuck wrench to stand	0.060	
Total time for setting four chuck jaws	4.85	

TABLE 7

Remove Jaws from Table

Gisholt Boring Mills

Details of operation	Size of Machine, Inches		
	30	36	42
	Time in Minutes		
1. Obtain chuck wrench from stand	0.035	0.040	0.045
2. Loosen two screw in jaw	0.172	0.180	0.190
3. Remove jaw from slot to stand	0.040	0.050	0.060
4. Turn table 120 degrees	0.090	0.100	0.120
5. Repeat items 2, 3 and 4	0.302	0.330	0.370
6. Repeat items 2 and 3	0.212	0.230	0.250
7. Remove wrench to stand	0.035	0.040	0.045
Total time for removing three chuck jaws	**0.89**	**0.97**	**1.08**

Details of operation	Size of Machine Inches	
	60	84
	Time in Minutes	
1. Obtain chuck wrench from stand	0.055	
2. Loosen four clamping bolts	0.440	
3. Remove jaw from slot to floor	0.160	
4. Repeat items 2 and 3	0.600	
5. Turn table 180 degrees	0.180	
6. Repeat twice items 2 and 3	1.200	
7. Remove wrench to stand	0.055	
Total time for removing four chuck jaws	**2.69**	

TABLE 8

REVERSE JAWS ON TABLE

GISHOLT BORING MILLS

Details of operation	Size of Machine, Inches		
	30	36	42
	Time in Minutes		
1. Obtain rule, measure diameter of piece	0.120	0.120	0.120
2. Obtain chuck wrench from tool stand	0.035	0.040	0.045
3. Loosen two clamping screws on jaw	0.172	0.180	0.190
4. Remove jaw from slot	C.050	0.055	0.060
5. Reverse jaw, enter in slot to line	0.089	0.093	0.100
6. Tighten two clamping screws on jaw	0.210	0.220	0.230
7. Turn table 120 degrees	0.090	0.100	0.120
8. Repeat items 3, 4, 5 and 6	0.521	0.548	0.580
9. Turn table 120 degrees	0.090	0.100	0.120
10. Repeat items 3, 4, 5 and 6	0.521	0.548	0.580
11. Remove wrench to stand	0.035	0.040	0.045
Total time for removing three jaws	1.93	2.04	2.19

Details of operation	Size of Machine Inches	
	60	84
	Time in Minutes	
1. Obtain rule, measure diameter of piece	0.150	
2. Obtain chuck wrench from stand	0.055	
3. Loosen four clamping bolts on jaw	0.440	
4. Remove jaw from slot	0.070	
5. Reverse jaw	0.060	
6. Enter base in table slot, outer edge flush with table	0.120	
7. Screw jaw in base to suit diameter of work	0.270	
8. Move jaw base to line	0.160	
9. Tighten four clamping bolts on jaw	0.440	
10. Repeat items 3, 4, 5, 6, 7, 8 and 9	1.560	
11. Turn table 180 degrees	0.180	
12. Repeat twice items 3, 4, 5, 6, 7, 8 and 9	3.120	
13. Remove wrench to tool stand	0.055	
Total time for reversing four jaws	6.68	

TABLE 9

Move Jaws In or Out to Line

Gisholt Boring Mills

Jaws on Table at Beginning of Job

Details of operation	Size of Machine, Inches		
	30	36	42
	Time in Minutes		
1. Obtain rule, measure diameter of piece........	0.120	0.120	0.120
2. Obtain chuck wrench from tool stand.........	0.035	0.040	0.045
3. Loosen two clamping screws in jaw.	0.172	0.180	0.190
4. Move jaw up to line.......................	0.080	0.093	0.100
5. Tighten two clamping screws on jaw..........	0.210	0.220	0.230
6. Turn table 120 degrees......................	0.090	0.100	0.120
7. Repeat items 3, 4 and 5.....................	0.471	0.493	0.520
8. Turn table 120 degrees......................	0.090	0.100	0.120
9. Repeat items 3, 4 and 5.....................	0.471	0.493	0.520
10. Remove chuck wrench to tool stand..........	0.035	0.040	0.045
Total time for moving three jaws	**1.79**	**1.88**	**2.01**

Details of operation	Size of Machine, Inches	
	60	84
	Time in Minutes	
1. Obtain rule, measure diameter of piece..................	0.150	
2. Obtain chuck wrench from tool stand	0.055	
3. Loosen four clamping bolts in jaw	0.440	
4. Move jaw base back, edge flush with table..............	0.070	
5. Screw jaw in base to suit diameter of work.............	0.270	
6. Move jaw to line	0.160	
7. Tighten four clamping bolts in jaw.....................	0.440	
8. Repeat items 3, 4, 5, 6 and 7..........................	1.380	
9. Turn table 180 degrees	0.180	
10. Repeat twice items 3, 4, 5, 6 and 7....................	2.760	
11. Remove chuck wrench to tool stand.....................	0.055	
Total time for moving four jaws.......................	**5.96**	

CHAPTER IX

LANDING WORK AND OPERATIONS PREPARATORY TO MACHINING

LANDING a piece of work on the table of a boring mill entails the use of a traveling crane or other type of hoist, unless the piece weighs less than a hundred pounds and is neither unusually bulky nor difficult to handle, when it can be picked up by hand and placed in the machine. This arbitrary classification by weight of method for handling the work from the floor to the machine is naturally subject to considerable latitude, but it is highly improbable that a piece of work weighing over a hundred pounds will be regularly picked up by hand in any efficiently conducted shop. As a matter of fact, the division between hand and crane operation will much more frequently occur around the seventy-five-pound mark. Furthermore, in landing the work on the boring-mill table it is assumed that the work has already been brought to the particular machine and placed conveniently in its close proximity. In the case of pieces which can be handled by hand this means that the work should be placed at a point not more, on the average, than six feet from the boring mill.

The averages of a comprehensive series of time studies made to ascertain the time required to pick up from the floor and to land a piece of work—the work not more than six feet from the machine and the weight of the piece varying from five to one hundred pounds—are given in Table 10. The operation consisted simply in the manual one of picking up the work with the hands and placing it upon the table of the boring machine.

TABLE 10

LAND PIECE FROM FLOOR TO CHUCK JAWS ON MACHINE BY HAND

GISHOLT BORING MILLS

Details of Operation	WEIGHT IN POUNDS										
	5	10	20	30	40	50	60	70	80	90	100
1. Pick up piece (six feet away) and land in chuck jaws on boring mill table by hand	0.10	0.11	0.127	0.148	0.173	0.20	0.23	0.26	0.29	0.32	0.35

When the work piece has to be slung in order to hoist it with ease and safety there are a number of ways in which it can be done and a diversity of suitable slings. Among the most commonly used machine-shop slings is the endless rope or endless chain, and a large steel ring with two, three or four

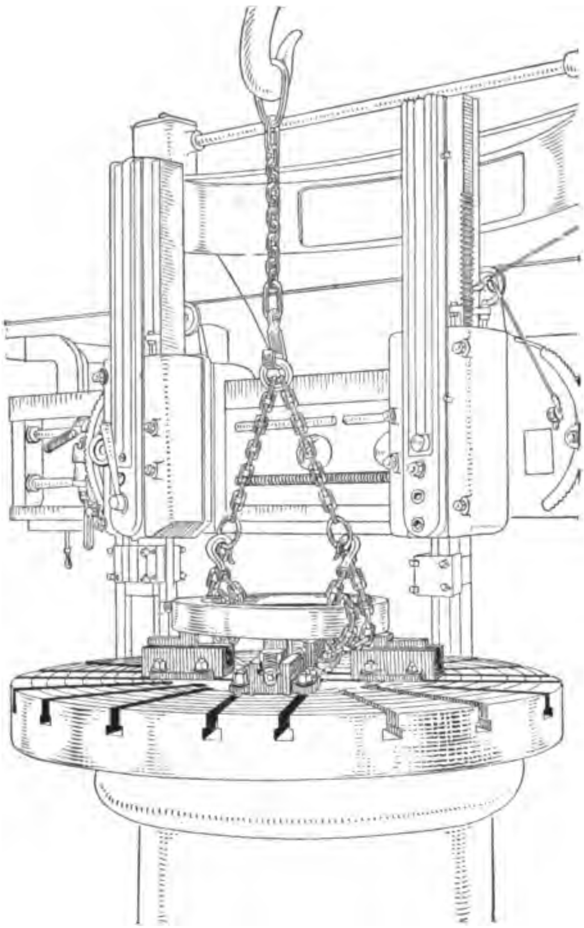


FIG. 44.—LANDING THE WORK BY HOIST

chains linked to it, each chain having at its free end a lifting hook. See Fig. 44.

Another method is to use a rope sling, looping one end around the piece itself, passing the bight over the crane hook and looping the free end around the opposite side of the piece. The end of the sling is then passed between the two ropes

forming one leg of the bight and a bar passed through the loop in the end, after which the sling is made taut. The latter method is applicable only to light work.

In all work that is to be handled by a crane the next piece which is to be placed in the machine should be handled before the crane is permitted to depart. If, on account of the conditions in the shop long waits are necessary before the crane is available, the time allowed for waiting for the crane should be

TABLE 11

DETAIL TIME TO SECURE CHAINS ABOUT WORK AND HOIST

GISHOLT BORING MILLS

Details of Operation	Weight in Pounds		
	To 150	Above 500	About 1000
	Time in Minutes		
1. Crane moved over work	0.20	0.20	0.20
2. Loop chains about work	0.56	0.76	0.88
3. Make chains taut	0.08	0.11	0.13
Total, securing chain to hoist	**0.84**	**1.07**	**1.21**
4. Hoist and land	See Table 11*A*		
5. Remove chains of sling about work	0.19	0.23	0.26
Total, removing chains after piece has been landed.	**0.19**	**0.23**	**0.26**

Tools required: One-inch rope sling; wooden bar, 2 x 4 x 43 inches.

added as an item in the time allowed for removing the piece from the machine whether the man takes advantage of this allowance each time he removes the piece from the machine or not.

The detailed operations involved in securing chain sling to land the work from the floor to the table of the boring mill by a power crane are listed in Table 11, with the unit times for each elementary act, and in Table 11*A*, the detail or unit times for the hoisting and landing operations are given for work

varying in weight from 90 to 1,250 pounds. In the latter table, values of the time required for the complete operation are also given.

TABLE 11A

DETAIL TIME OF OPERATION TO CHUCK JAWS ON HOIST PIECE FROM FLOOR AND LAND IN MACHINE

GISHOLT BORING MILLS

Detail of Operations	WEIGHT IN POUNDS											
	90	100	125	150	200	250	300	400	500	700	1000	1250
1. Secure chain to hoist (Table 11).......	0.84	0.84	0.84	0.84	1.07	1.07	1.07	1.07	1.07	1.21	1.21	1.21
2. Hoist (about four ft.)	0.10	0.10	0.10	0.10	0.102	0.103	0.104	0.107	0.11	0.117	0.135	0.155
3. Travel to machine table (fifteen feet).	0.15	0.15	0.15	0.151	0.155	0.16	0.165	0.175	0.185	0.205	0.238	0.270
4. Lower and land piece in jaws..........	0.11	0.110	0.11	0.113	0.117	0.12	0.123	0.13	0.136	0.153	0.175	0.195
5. Removing chain after piece has been landed (Table 11).	0.19	0.19	0.19	0.19	0.23	0.23	0.23	0.23	0.23	0.260	0.260	0.260
Total time to hoist and land........	1.39	1.39	1.39	1.394	1.647	1.683	1.692	1.712	1.731	1.945	2.018	2.090
Total for practical use	1.40				1.70					2.00		

Tools required: 10-ton Shaw electric traveling crane, or crane of similar hoisting speed.

The tables show the time required to loop the chain over the bar, and place the bar in position under the piece to be lifted, and also the time required for making the sling taut after hooking on the crane.

For landing work, whether by hand or hoist, distinction is made in the tables according to the weight of the piece. Times for a piece as light as 90 pounds are shown for handling by hoist, and times for a piece as heavy as 100 pounds are given for handling by hand. On small machines most operators can handle pieces of 100 pounds by hand without over exertion. Where a great many pieces are to be worked upon it is probably advisable to count on handling by hand, for few operators will bother with a crane and the waits connected with it, but in ordinary cases 80 pounds in weight is about the maximum for handling by hand. In the tables in this article it is assumed that where a piece is handled by hand, the man walks about 6 feet from the machine, picks up the piece, returns to the machine, lifts it a distance of 3½ feet and lands it in the chuck jaws.

In handling a piece by the crane, the piece is first slung by one of the approved methods and is then hoisted about 4 feet before being transferred to the machine. The table assumes a movement of 15 feet from the pile of pieces to the chuck jaws. In all cases of slinging the sling must be removed when the piece has been landed at its destination.

The work landed on the table of a boring mill, it is necessary to make the piece run true with reference to the circumference of the machine table, but this operation rarely has to be repeated more than twice in repetitive manufacture unless very accurate setting of the piece is necessary. In general, the operation of truing the work may be divided into two classes: 1. For single pieces; 2. For duplicate pieces.

For duplicate pieces the operation necessary for single pieces must be performed for the first piece of the lot and, sometimes, for the first two pieces. After that the same chuck jaw or jaws should be opened each time for the removal of the piece, and those that are to be opened should be prominently marked. If this is done truing the piece of work becomes unnecessary, it is simply placing a piece in the chuck jaws and tightening the jaws that were previously opened.

For single pieces the process of truing is as follows: The piece having been landed in the chuck jaws, the workman procures his chuck wrench, tightens the jaws upon the piece, and lays down the wrench. He then rapidly travels the head over to the edge of the piece and puts a finger in the tool post to facilitate testing the trueness of the piece. The time for this item is the time required to rapidly travel the head from its normal position at the end of the cross rail to the edge of a piece 66 per cent. of the diameter of the table. (This approximation can be used for the ordinary run of work. If, however, a piece is being machined that is disproportionate to the size of the machine the time for rapid travel should be taken that relates to the particular operation.) The test finger being in place the table is started and the concentricity of the piece is tested and the table stopped. By adjusting the proper jaws, if the work does not run true, the piece is brought more nearly concentric with the table and its condition is again examined by starting the table and testing with the test finger. This operation is repeated until the piece runs true. Then all the jaws are tightened, the chuck wrench is removed to the tool stand and the test finger is taken from the tool post.

Ordinarly the finger test for concentricity of work does not have to be repeated more than three times for work on boring mills up to the 42-inch size and not more than four times in the case of larger mills. These limits were employed in the compilation of the time table, Table 12, where the unit times allowed for the repetition of the finger tests are included in the totals for the various sizes of machines. The number of tests for which time is provided should be ample for a skilled work-

man to true up the work. Table 12 itemizes the operations necessary to true up a casting or smooth forging that does not require very accurate setting, while Table 12*A* gives the time required to tighten the chuck jaws on the work and lists all elementary operations, with their allowed unit times, for so doing.

TABLE 12

DETAIL TIME OF OPERATION TO MAKE PIECE RUN TRUE IN CHUCK JAWS

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
Number of jaws tightened on piece after landing*	1	1	2	2	2
1. Pick up wrench, tighten jaws on piece and lay wrench down (Table 12*A*)	0.44	0.49	0.54	0.80	....
2. Rapid travel head (to use head as rest to test trueness)	0.43	0.38	0.48	0.40	....
3. Put finger in post †	0.22	0.23	0.24	0.27	....
4. Start table test for trueness (with chalk) and stop table	0.35	0.39	0.43	0.45	....
5. Set piece true by adjusting jaws	0.22	0.25	0.28	0.60	....
6. Repeat item 4	0.25	0.28	0.30	0.45	....
7. Repeat item 5	0.22	0.25	0.28	0.60	....
8. Repeat item 4	0.25	0.28	0.30	0.45	....
9. Repeat item 5	....	....	....	0.60	....
10. Repeat item 4	....	....	....	0.45	....
11. Tighten all jaws tight and remove wrench to tray (Table 12*A*)	0.31	0.49	0.55	0.72	....
12. Remove finger from post	0.11	0.12	0.13	0.16	....
13. Rapid travel head over to one side	0.43	0.38	0.48	0.40	....
Total	3.23	3.54	4.01	6.35	....

Tools required: Chuck jaw wrench.

* Number of jaws indicated are those that are tightened on the piece as soon as it has been arranged in place.

† Usually this indicating finger is a very small device consisting of a piece of wood with a nail driven into the end so that when the head of the boring mill is moved over this nail is in such a position that it can be used as an indicator to test the trueness of the piece. It is evident that anything that will present a sharp point to the work will do just as well.

Obviously, there are many ways of holding the work securely on the tables of boring mills, the most common one being the use of three- or four-jawed chucks. Tables 12 and 12*A* give detailed times for the operation of the type of chucks illus-

trated in Figs. 42 and 43, Chapter VIII. In most cases the use of chuck jaws are limited to cylindrical pieces that will allow the jaws to get a grip. However, in a modern boring mill the chucks are usually of substantial design and are

TABLE 12A

Detail Time of Operation to Tighten Jaws on Work

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
Number of jaws tightened on piece after landing.........	1	1	2	2	2
1. Pick up wrench, tighten jaws on piece and lay wrench down....................	0.44	0.49	0.59	0.80	....
2. Tighten all jaws tight and remove wrench to tray.......	0.31	0.49	0.55	0.72	....
Total time for tightening.....	0.75	0.98	1.14	1.52	....

Tools required: Chuck jaw wrench.

convenient for a wide variety of work. On some of the older types of mills, on the other hand, the work must be held by straps, clamps and bolts. The heads of the bolts enter T-slots in the table. Furthermore, besides the clamps, it is necessary to set stops to prevent the work from moving, so that additional time is required to clamp the work securely in position. Even on the modern mills fitted with chucks certain pieces sometimes require straps or clamps and stops in addition to the gripping action of the chuck jaws, for which additional time must be provided.

CHAPTER X

SETTING TOOLS AND MANIPULATING BORING MILL TO START CUTS

WHEN the preparatory operations of landing the work on the boring-mill table and the manipulation required to set the piece to run true and to secure it in the machine have been performed, then the tools have to be set and the machine manipulated before commencing the actual operation of removing metal. If several cuts have to be taken or if the machining of more than one surface is called for, the setting of tools and the manipulation of the machine may occur several times, also the removal of tools, with machining operations interspersed. In the actual performance of the complete machine operation the sequence of fundamental operations has to be strictly adhered to, but in presenting elementary time tables by which the rate for the various fundamental operations may be set, it is advisable to deviate considerably from the schedule of operations, particularly as all of the fundamental operations which may be performed on the machine need not be necessary for a particular piece of work, or the order in which the fundamental operations are performed may differ. Elementary time tables covering the rate at which tools should be set and removed and for the manipulation of the machine previous to starting cuts for Gisholt boring mills from 30 to 84 inches in size will be presented collectively, for this reason, even though the removal of metal takes place between the fundamental operations of setting tools and manipulating the machine for the various cuts.

The workman is assumed to be at the operating position at the end of the rail before beginning each operation and he procures both the tool and the tool post wrench from the tool stand at the same time. He inserts the tool for the first cut in the post, tightens the set screw and returns the wrench to the tool stand These are acts common to all tool setting operations, irrespective of the type of tool or the surface machined, are somewhat more complicated in the case of the finishing tools, or if the tool is placed in the left-hand head of the larger boring mills (42-, 60- or 84-inch)—the head to the left of the workman

as he stands in front and faces the machine—an additional time allowance should be made. Ordinarily the tools are used in the right-hand head and the operations of setting the tools in the left-hand head are identical, but the workman has to traverse a somewhat greater distance to place the tools in the left-hand head. In the case of finishing tools, more adjustment of tool is necessary than when setting a roughing tool. The detailed operations and unit times for the various acts in setting tools for the different sizes of mills are itemized in Tables 13, 13-*a*, 13-*b*, 13-*c*, 13*A*, 13*A-a*, 13*A-b* and 13*A-c*.

TABLE 13

SETTING TOOLS IN TOOL POST AND TIGHTENING FOR ROUGHING CUT ON OUTSIDE DIAMETER—ROUND-NOSE TOOL IN RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Obtain tool and wrench from stand	0.060	0.060	0.065	0.080	0.090
2. Put tool in post	0.040	0.042	0.045	0.055	0.060
3. Tighten ¾-in. set screw	0.140*	0.210†	0.210†	0.210†	0.210†
4. Remove wrench to stand	0.035	0.040	0.045	0.055	0.070
Total time to set tool	0.28	0.35	0.37	0.40	0.43

Tools required: Open end wrench.
Normal position of man: At end of cross rail.

* Two sets screws to tighten.
† Three set screws to tighten.

TABLE 13-*a*

SETTING TOOLS IN TOOL POST AND TIGHTENING FOR ROUGHING CUT ON FACE—ROUND-NOSE TOOL IN RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
Total time to set tool	0.28	0.28	0.30	0.36	0.36

NOTE: The operations in setting a roughing tool for a facing cut are the same as those in setting it for a cut on an outside diameter, as given in Table 13, with the exception that only two set screws are tightened in the tool post.

TABLE 13-*b*

SETTING TOOL IN TOOL POST AND TIGHTENING FOR ROUGHING CUT ON OUTSIDE DIAMETER—ROUND-NOSE TOOL IN LEFT-HAND HEAD

GISHOLT BORING MILLS

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for setting tools as in Table 13	0.365	0.400	0.430
2. Additional time required to walk to left of machine and return	0.096	0.110	0.160
Total time required to set tool	0.46	0.51	0.59

Tools required: Open end wrench.
Normal position of man: At end of cross rail.

TABLE 13-*c*

SETTING TOOLS IN TOOL POST AND TIGHTENING FOR ROUGHING CUT ON FACE—IN LEFT-HAND HEAD

GISHOLT BORING MILLS

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for setting tool as in Table 13-*a*	0.295	0.330	0.360
2. Additional time required to walk to left side of machine and return	0.096	0.110	0.160
Total time for setting tool	0.39	0.44	0.52

NOTE: The operations for setting tools in the left-hand head of the various machines are the same as for setting them in the right-hand head. The workman, however, has a longer distance to walk from the tool stand to the head and return, necessitating an additional time allowance.

If roughing tools are used in both the right-hand and left-hand heads no time, as a rule, should be allowed for the setting of the second roughing tool when preparing the instruction card. This second tool should be placed in the tool post after the machine has been started and after the first tool is actually engaged in removing metal. An exception to this practice may be permitted if considerations of safety require the workman to

stop the machine while he is performing the operation "put tool in post and tighten set screw." In this event time should be allowed for stopping and starting the machine, but none for procuring the wrench and tool nor for removing the wrench to the stand after the second tool is set in place.

TABLE 13*A*

SETTING TOOLS IN TOOL POST AND TIGHTENING FOR FINISHING CUT ON OUTSIDE DIAMETER—SQUARE NOSE TOOL IN RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Obtain tool and wrench from stand .	0.060	0.060	0.065	0.080	0.090
2. Put tool in post with cutting edge against work	0.140	0.150	0.160	0.190	0.230
3. Tighten lightly ¾-in. set screws	0.140*	0.210†	0.210†	0.210†	0.210†
4. Set head back for clearance	0.040	0.040	0.040	0.050	0.070
5. Start table, test tool for bearing and stop table	0.190	0.190	0.190	0.200	0.210
6. Adjust tool to bearing	0.170	0.170	0.180	0.190	0.200
7. Start table, test tool for bearing and stop table	0.190	0.190	0.190	0.200	0.210
8. Tighten firmly ¾-in. set screws	0.140*	0.210	0.210	0.210	0.210
9. Remove wrench to tray	0.035	0.040	0.045	0.055	0.070
Total time to set tool	1.11	1.26	1.29	1.39	1.50

* Two set screws to tighten.
† Three set screws to tighten.

TABLE 13*A-a*

SETTING TOOLS IN TOOL POST AND TIGHTENING FOR FINISHING CUT ON FACE—SQUARE NOSE TOOL IN RIGHT-HAND HEAD

GISHOLT BORING MILLS

	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
Total time to set tool	1.11	1.12	1.15	1.25	1.36

NOTE: The operations in setting a finishing tool for a facing cut are the same as those in setting it for a cut on an outside diameter, as given in Table 13*A*, with the exception that only two set screws are tightened.

TABLE 13*A*-*b*

SETTING TOOL IN TOOL POST AND TIGHTENING FOR FINISHING CUT ON OUTSIDE DIAMETER—SQUARE NOSE FINISHING TOOL IN LEFT-HAND HEAD

GISHOLT BORING MILLS

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for setting tool as in Table 13*A*	1.290	1.385	1.500
2. Additional time required to walk to left side of machine and return	0.096	0.110	1.160
Total time for setting tool	1.39	1.50	1.66

TABLE 13*A*-*c*

SETTING TOOL IN TOOL POST AND TIGHTENING FOR FINISHING CUT ON FACE—LEFT-HAND HEAD

GISHOLT BORING MILLS

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for setting tool as in Table 13*A*-*a*	1.150	1.245	1.360
2. Additional time required to walk to left side of machine and return	0.096	0.110	0.160
Total time for setting tool	1.25	1.36	1.52

The operation item "obtain tool and wrench from stand" may be combined in the instruction card with the final element of the operation of squaring and levelling work, as the workman removes his tools for that operation to the tool stand. In such event the time allowed on the instruction card for the final element of squaring and levelling, and for the unusual element for squaring the tool should be one half the sum of the times for these two operation items as given on the tables of the

respective operations. However, unless parts are made in large quantities, the saving in time by eliminating a few elements from the fundamental operations is not good practice. Rather than eliminate such elements, it would be better to build up fundamental operation tables for the more special conditions, provided, of course, there was sufficient call for such tables. It depends upon whether the special tables would be used sufficiently often to warrant their compilation.

When setting square nose finishing tools the tool is placed in the tool post with its cutting edge against the work and two of the tool post screws are tightened lightly against it The tool is then ratcheted back about $\frac{1}{32}$ inch to provide clearance and the machine is started to test the bearing of the tool on the

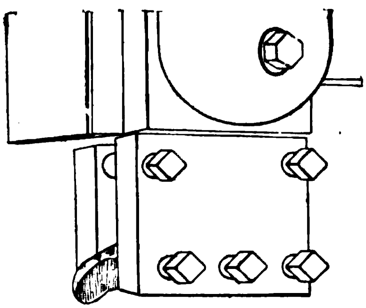


FIG. 45.—TOOL FOR ROUGHING CUT ON OUTSIDE DIAMETERS

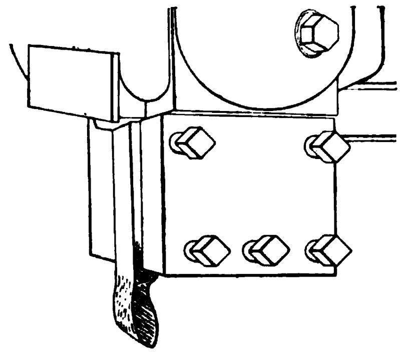


FIG. 46.—TOOL SET FOR ROUGH FACING CUT

work. If it is not set properly, it is adjusted by tapping it lightly while the machine is running, or by stopping the table and making a still greater adjustment If the table has been stopped, it is then re-started and the tool again tested for bearing. If it is now found to be square with the work the tool-post set screws are screwed up and the wrench is removed to the tool stand. This testing and adjusting should be repeated as often as may be necessary until the tool is set square with the work. In the following tables, however, allowance has been made for only one adjustment, for this should be ample for a skilled workman.

If square nose finishing tools are used in both heads at the same time—although this practice is not to be recommended—the time allowed should be the total times given in Tables 13*A* and 13*A-c* or 13*Aa* and 13*A-b*, inasmuch as the tool

cannot be set square and the various adjustments made with the table in motion.

The operations of setting square nose tools may be combined with the final element of the previous operation, as has been explained above for round nose roughing tools. If this is done the necessary deduction should be made from the tabulated time to cover the saving made by combining the several elements of the two operations.

On completion of the first cut, roughing cut, the round-nose tool (Fig. 45) has to be removed from the tool post and replaced, with the wrench, on the tool stand. A similar operation should be performed on the completion of any other cut. The removal of the tool requires first the loosening of the holding screw, the removal of the tool from the post and the placing of the tool and wrench on the tool stand. Elementary time tables covering these operations for roughing and finishing tools in either hand head, giving the operation details and unit times, are given as Tables 14, 14-*a*, 14*A* and 14*A-a*.

The tables relating to the operation of removing the tool from the tool post assume that the workman has stopped the machine

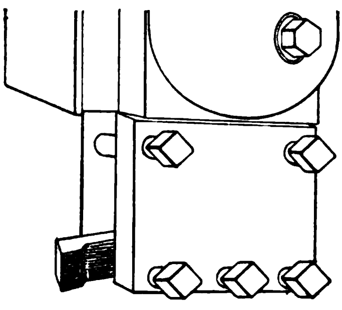


FIG. 47.—TOOL FOR FINISHING CUT ON OUTSIDE DIAMETERS

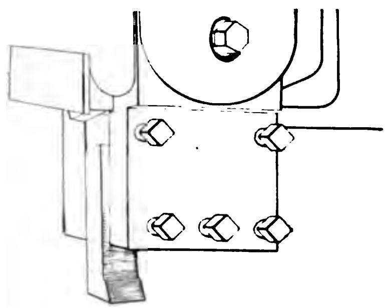


FIG. 48.—FINISHING TOOL SET FOR FACING CUTS

from his operating position at the end of the cross rail. He obtains a wrench from the tool stand, loosens the tool-post set screws and removes both wrench and tool to the stand.

Ordinarily tools are used in the right-hand head only of double head machines. If, however, the left-hand head is not used the workman will have to traverse a greater distance between the tool stand and the head. This additional travel taken into account in Tables 14-*a* and 14*A-a* and these tables should be used in preparing an instruction card to cover this situation.

If tools are used in both heads, the time allowed on the card should be the same as the times allowed in Tables 14 or 14*A*, and 14-*a* or 14*A*-*a*, if the workman is to remove the two tools separately to the stand. If, however, he is to remove the tool from one head and carry it and the wrench to the other head, remove the second tool and then transfer both tools to the tool stand at the same tme, strictly speaking, a deduction should be made of items 1 and 3 of Table 14, inasmuch as these items will appear but once. In practice the time expending in making these deductions does not usually warrant taking them into account. If there is much use for such fundamental tables they should be made up. A detailed instruction card covering this operation for a 42-inch mill will be as follows:

	Time in Minutes
1. Obtain wrench from stand (Item 1, Table 14)	0.060
2. Loosen (3) ¾-inch set screws, right-hand head (Item 2, Table 14)	0.150
3. Move to left-hand head (½ of Item 2, Table 14*A*)	0.048
4. Loosen (3) ¾-inch set screws, left-hand head (Item 2, Table 14)	0.150
5. Return tools and wrench to stand (½ Item 2, Table 14*A*, plus Item 3, Table 14)	0.098
Total time for removing both tools	**0.506**

An exception to the rule for allowing additional time for the removal of the second tool is made in those cases where the two tools are so far apart in their cuts that there is ample time to remove the first tool before the second one has finished its cut. In this event the workman will move the head back from the work while the machine is in motion as soon as the first tool reaches the end of its cut and removes that tool. No allowance need be made for this operation.

TABLE 14

LOOSEN AND REMOVE SQUARE AND ROUND NOSE TOOLS SET FOR CUTS ON OUTSIDE DIAMETERS—RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Obtain wrench from stand	0.050	0.050	0.060	0.070	0.080
2. Loosen ¾-in. set screws	0.100*	0.150†	0.150†	0.150†	0.150†
3. Remove tool and wrench to stand	0.040	0.045	0.050	0.060	0.080
Total time to remove tool	0.19	0.25	0.26	0.28	0.31

* Two set screws to loosen. † Three set screws to loosen.

Table 14-a

Loosen and Remove Square and Round Nose Tools Set for Cuts on Outside Diameters—Left-hand Head

Gisholt Boring Mills

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for removing tool as in Table 14	0.260	0.280	0.310
2. Additional time required to walk to left of machine and return	0.096	0.110	0.160
Total time for removing tool	0.36	0.39	0.47

TABLE 14*A*

Loosen and Remove square and Round Nose Tools Set for Cuts on Face—Right-hand Head

Gisholt Boring Mills

	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
Total time to remove tool	0.19	0.20	0.21	0.23	0.26

Note: The operations for removing tools set for a cut on face, from the tool post are the same as for a tool set for a cut on an outside diameter, excepting that there are but two set screws to loosen.

TABLE 14*A*-*a*

Loosen and Remove Square and Round Nose Tools Set for Cuts on Face—Left-hand Head

Gisholt Boring Mills

	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Time for removing tools as in Table 14*A*	0.210	0.230	0.260
2. Additional time required to walk to left side of machine and return	0.096	0.110	0.160
Total time to remove tool	0.31	0.34	0.42

Note: The operations for removing tools from the left-hand head of the various machines are the same as for removing them from the right-hand head. The workman, however, has a longer distance to walk from the tool stand to the head and return, necessitating an additional time allowance.

Though the foregoing operations cover the actual setting of the tool in the tool post, considerable manipulation of the boring mill is required before the tool can be set for depth of cut or the act of machining actually started. For instance, the motor of the machine has to be started or stopped, also the boring-mill table, possibly the speed or the feed gears have to be changed and in all cases the turret head has to be locked or unlocked. These fundamental operations with the time required for each are listed in Table 15, including the time for the incidental elementary acts. The turret heads also have to

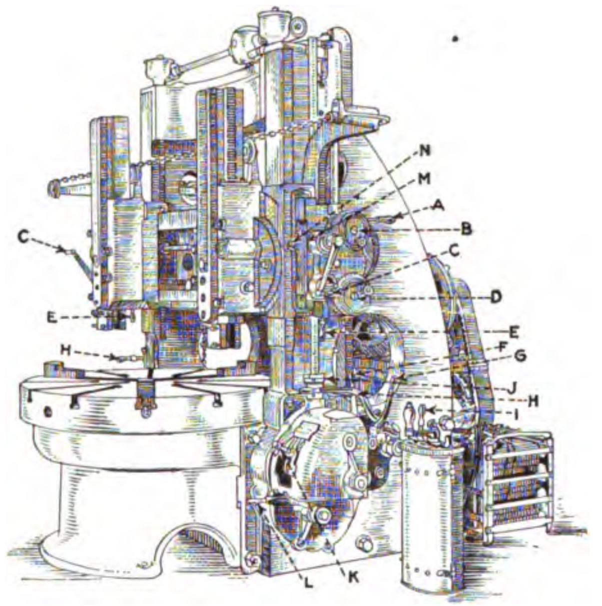


FIG. 49.—GISHOLT BORING MILL

be manipulated prior to the starting of a cut. For boring mills of the 30-, 36- and 42-inch types, the turret heads have to be loosened, revolved and tightened—unit times for which acts are given in Table 15*A*, and also the total time required for revolving the turret heads for the three types of boring mills. The ram head of 30-inch mills are moved by hand levers—see Table 15*A-a*—but the ram heads of larger types of boring mills are moved by power through the manipulation of certain levers)—see Table 15*A-b* and Fig. 49.

TABLE 15

MACHINE MANIPULATION

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
Start Motor—			
1. Walk to motor	0.050	0.060	0.070
2. Start motor by controller	0.060	0.060	0.060
Total time for starting motor	0.11	0.12	0.13
Stop Motor—			
1. Walk to controller	0.050	0.060	0.070
2. Stop motor by controller	0.030	0.030	0.030
Total time for stopping motor	0.08	0.09	0.10
Start Table—			
1. Start table	0.04	0.04	0.04
Stop Table—			
1. Stop table	0.04	0.04	0.04
Change Speed Gears—			
1. Walk to speed change levers	0.050	0.060	0.070
2. Change speed	0.100	0.130	0.130
3. Return to operating position	0.030	0.030	0.030
Total time to change speed	0.18	0.22	0.23
Change Feed Gears—			
1. Walk to feed box	0.050	0.060	0.070
2. Change position of feed box*	0.070	0.070	0.070
3. Return to operating position	0.030	0.030	0.030
Total time to change feed	0.15	0.16	0.17

Locking and Unlocking Head	Size of Machine in Inches				
	30	36	42	60	84
1. Tighten set screws to lock head against vertical movement	0.110	0.110	0.110	0.120	0.140
2. Loosen set screws to unlock head	0.110	0.110	0.110	0.120	0.140

* If both feed levers are to be manipulated, 0.04 minute should be added to the totals for each manipulation of lever L.

TABLE 15A

Manipulate Turret Head—Loosen, Revolve Turret and Tighten

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamping lever	0.03	0.03	0.03
2. Hold down locking lever	....	....	....
3. Revolve turret	0.03	0.03	....
4. Release locking lever	....	....	....
5. Raise locking pin lever	....	....	....
6. Revolve and set turret	....	....	0.94
7. Clamp locking pin lever	....	....	....
8. Tighten clamping lever	0.03	0.03	0.03
Total time for revolving turret	**0.09**	**0.09**	**0.10**

TABLE 15A-a

Manipulate Levers to Travel Ram Head by Hand for 30-inch Machine

Gisholt Boring Mills

1. Procure wrench from tool stand	0.040	Note: A + B = C, the desired distance that the ram head is to be moved.
2. Place crank on screw	0.020	
3. Crank head in or out, column B below	.....	
4. Remove crank from screw	0.050	
Total handling time	**0.110**	(See Col. A below)*

Distance of Travel in Inches	Handling Time	Time for Horizontal Travel	Total Horizontal Travel and Handling Time	Time for Vertical Travel	Vertical Travel and Handling Time
	A	B	C		
1	0.110	0.090	0.200	0.040	0.150
2	0.110	0.105	0.215	0.045	0.155
3	0.110	0.130	0.240	0.050	0.150
4	0.110	0.165	0.275	0.060	0.170
5	0.110	0.200	0.310	0.065	0.175
6	0.110	0.250	0.360	0.075	0.185
8	0.110	0.340	0.450	0.095	0.205
10	0.110	0.440	0.550	0.115	0.225
12	0.110	0.545	0.655	0.135	0.245
15	0.110	0.700	0.810	0.170	0.280

* Refer to crank *C* in illustration of machine with operating levers indicated.

Note: If the direction of the travel is changed from horizontal to vertical or vice versa, 0.040 minute should be added to the above totals to cover the changing of crank from one screw to the other.

TABLE 15A-b

Manipulate Levers to Rapid Travel Ram Head by Power

Gisholt Boring Mills

1. Grasp handle F, engage clutch	0.014	Note: A + B = C,
2. Start rapid travel handle E	0.008	the desired distance the ram
3. Engage trip lever	0.008	head is to be
4. Rapid travel, see column B below	.....	moved.
5. Stop travel, throw out three levers	0.030	
Total manipulation time	0.60	(See column A below)

36-Inch Machine				42-Inch Machine			
Distance of Travel in Miles	A Manipulating Time	B Travel Time Horizontal or Vertical	C Total Rapid Travel Time	Distance of Travel in Miles	A Manipulating Time	B Travel Time Horizontal or Vertical	C Total Rapid Travel Time
1	0.060	0.031	0.091	1	0.060	0.018	0.078
2	0.060	0.062	0.122	2	0.060	0.037	0.097
3	0.060	0.093	0.153	3	0.060	0.055	0.115
4	0.060	0.124	0.184	4	0.060	0.073	0.133
5	0.060	0.155	0.215	5	0.060	0.092	0.152
6	0.060	0.186	0.246	6	0.060	0.110	0.170
8	0.060	0.248	0.308	8	0.060	0.147	0.207
10	0.060	0.310	0.370	10	0.060	0.183	0.243
12	0.060	0.372	0.432	12	0.060	0.220	0.280
16	0.060	0.496	0.556	16	0.060	0.293	0.353
				20	0.060	0.367	0.427

60-Inch Machine				84-Inch Machine			
Distance of Travel in Miles	A Manipulating Time	B Travel Time Horizontal or Vertical	C Total Rapid Travel Time	Distance of Travel in Miles	A Manipulating Time	B Travel Time Horizontal or Vertical	C Total Rapid Travel Time
3	0.060	0.050	0.110	3	0.060	0.050	0.110
4	0.060	0.066	0.126	4	0.060	0.060	0.126
5	0.060	0.083	0.143	5	0.060	0.083	0.143
6	0.060	0.100	0.160	6	0.060	0.100	0.160
8	0.060	0.133	0.193	8	0.060	0.133	0.193
10	0.060	0.167	0.227	10	0.060	0.167	0.227
12	0.060	0.200	0.260	12	0.060	0.200	0.260
16	0.060	0.267	0.327	16	0.060	0.267	0.327
20	0.060	0.333	0.393	20	0.060	0.333	0.393
24	0.060	0.400	0.460	24	0.060	0.400	0.460
				32	0.060	0.534	0.594
				40	0.060	0.666	0.726

If direction of travel is changed, 0.014 minute should be added to the above travel times.
Example: If on a 36-inch machine the head is to be moved 12 inches horizontally and 6 inches vertically, the time for horizontal travel would be 0.432 minute, and for the vertical travel 0.106 plus 0.014 equals 0.120 minute.

Various combinations of feeds, speeds, etc., are obtained by manipulation of the levers shown in Fig. 49. These are for the operating tests at either end of the cross rail which are the normal positions for the workman in the following tabulation:

The functions of the several levers are as follows:

A. This lever controls the raising and lowering the cross rail, Fig. 49. It is used in connection with lever I.

E.E. These levers are used to engage the feed for either the vertical or horizontal heads. They are also used for reversing and stopping the feeds.

F. This lever controls the table speeds through sliding gears on the headstock. The three positions of the lever make available three speeds. The forward position gives the medium table speed; the middle position gives the fast speed; the back position gives the slow speed.

G. This lever controls the table movement. After the motor has been started the table may be started, stopped or moved a fractional part of a revolution by manipulating this lever.

K.L. These are the feed-change handles. There are five positions for lever K, while lever L, which operates the back gears has only two positions.

H.H. These are the rapid traverse levers for controlling all movements of the head. Manipulating either one automatically disengaged all feeds and moves the heads rapidly in the desired direction. Releasing the levers stops the rapid travel and causes the feed to resume operating. These levers are not found on the 30- or 36-inch machines.

C.C. These are the hand cranks for moving the heads when it is not desirable or necessary to use the rapid travel machine. They supply the only means of moving the heads on the 30- and 36-inch machines.

B.D. These refer to the vertical and horizontal feed-trip dials on either end of the rail. They automatically disengage the feed at any predetermined point and at the end of the rail or of the down-slide traverse.

M. This refers to the micrometer index dials on both feed screws.

Continual use will be made of items "starting table," "locking and unlocking head" in compiling the tables of "manipulating machines to set tool for depth and start cut." On the other hand, "starting and stopping motor" and "change speed and feed gears" are not put in such use in the combined tables.

The driving motor of the machine can be started and allowed to run continuously while the machine is in use, although

it is advisable to stop it when handling and removing the work. As this time of starting and stopping will only be required once or twice for a piece it should be taken care of in the preparation allowances. The changing of speed and feed gears can be done during the machining time, so no account need be taken of the time required for these movements.

It is customary—at least on any finish cut—to caliper, gage or measure cut diameters, or other dimensions, preparatory to commencing the actual removal of metal (the working cut). This necessitates short trial cuts to provide gaging surfaces, the time to take which, for convenience, is allowed and provided for in the machining time. That is, if a cut of a certain length has to be made a suitable trial cut or series of trial cuts for measuring purposes are considered as additional to the necessary working cut and the machining time should be calculated to include the time consumed for the trial cuts. The actual calipering, or gaging, may be performed by different methods and by numerous instruments, but typical of calipering time requirements are those for setting and trying of the ordinary hand and beam calipers given in Tables 16 and 16-*a*. These tables are based on the assumption that when a caliper trial is made, the calipers are carried to the machine during the machining process and held in the hand while the machine is running, so no time is allowed to take the calipers to or from the boring mill.

TABLE 16

SETTING CALIPERS TO SCALE

GISHOLT BORING MILLS

Details of Operation	Dimensions Calipers Are Set To, in Inches								
	5	10	15	20	25	30	36	40	45
	Time in Minutes								
1. Pick up and take calipers 12 feet	....	....	....	....	....	0.10	0.10	0.10	0.10
2. Set calipers by steel scale	0.23	0.24	0.27	0.32	0.37	0.44	0.52	0.64	0.72
3. Return calipers to stand 12 feet away	....	....	....	....	....	0.10	0.10	0.10	0.10
Total time to set calipers	0.23	0.24	0.27	0.32	0.37	0.64	0.72	0.84	0.92

NOTE: Up to 15 inches the calipers and scale are held in the hands; above 15 inches and up to 25 inches the scale is laid flat on the stand or machine table; up to 25 inches hand calipers are used. Above 25 inches beam calipers are used and it is supposed that a platen of some kind is at hand within 12 feet, where a scale of sufficient length can be laid flat to set the beam calipers for dimensions greater than 25 inches.

TABLE 16-*a*

TRY CALIPERS ON WORK

GISHOLT BORING MILLS

Operation: Try calipers on work in a horizontal position.
Tools: Calipers.

Details of Operation	Dimensions Calipers Are Set To, in Inches								
	5	10	15	20	25	30	35	40	45
	Time in Minutes								
1. Trying calipers on roughing cuts. Total time	0.19	0.19	0.20	0.21	0.22	0.23	0.25	0.28	0.32
2. Trying calipers on finishing cuts: Total time	0.19	0.19	0.21	0.22	0.25	0.28	0.32	0.36	0.41

Tools: Hand calipers up to 25 inches, beam calipers for larger dimensions and graduated scale.

In trying (calipering) diameters of cuts it is assumed that the workman takes the calipers to the machine, stops the mill and then, with the calipers on the cut, tries setting the cut deeper or shallower or allowing it to remain as it is, as may be required. The width of the trial cut for 30- and 36-inch mills is taken as 1/4 inch; for 42-inch machines, 5/16 inch; for 60-inch boring mills, 3/8 inch, and for mills of the 84-inch type, 1/2 inch.

In practice, such width of surface is turned on the work, the machine is stopped and the work calipered. The necessary adjustment of the tool is made to obtain the right dimension and the work is again turned and calipered. With roughing tools on machines of the 36-inch size, two such trials are usually sufficient to catch the correct diameter; on larger machines three trials are usually enough. With finishing tools two trials are considered sufficient for all sizes of machines. These numbers of trials are the basis on which the tables have been prepared.

The time required for starting a cut on any piece of work depends upon several factors, among them being the diameter of the piece, the shape of the piece, the size and shape of the tool, the nature of the material and quality (hardness or difficulty in cutting) of the material. These factors are accounted for by considering that the length of run of the tool, that is, the distance that the tool must traverse across the piece that is being machined, is somewhat longer than the actual length of the piece. This addition to the length of run ranges from

¼ to ½ inch and depends upon circumstances and the allowances for different conditions.

There are, however, certain other elements connected with the setting and starting of cuts for which definite time allowance are made and which are used in compiling the elementary time tables. These are starting and stopping the boring-mill table, the rapid travel of the ram head and the periodic calipering—the latter, similar to the calipering previously discussed. The sequence of the elements and the allowances that are made for them either in time or length of run are given in Tables 17 to 17*K*.

TABLE 17

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH, AND START FIRST CUT ON OUTSIDE DIAMETER

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over from end of rail (from normal position)......	0.31	0.246	0.207	0.227	0.293
2. Rapid travel head down..........	0.17	0.215	0.170	0.193	0.26
3. Start table..........	0.04	0.04	0.94	0.04	0.04
4. Set tool into work..........	0.18	0.19	0.21	0.26	0.35
5. ROUGH TURN for calipering (stop machine)..........	*	*	†	‡	¶
6. Caliper*..........	0.21	0.22	0.23	0.28	0.42
7. Start t bl	0.04	0.04	0.04	0.04	0.04
8. Reset tool into work..........	0.17	0.175	0.18	0.20	0.25
9. ROUGH TURN for calipering (stop machine)..........	*	*	†	‡	¶
10. Caliper*..........	0.21	0.22	0.23	0.28	0.42
11. Start table..........	....	....	0.04	0.04	0.94
12. Reset tool into work or out..........	....	....	0.18	0.20	0.25
13. ROUGH TURN for calipering (stop machine)..........		....	†	‡	¶
14. Caliper cut..........	....	....	0.23	0.28	0.42
15. Start table..........	0.04	0.04	0.04	0.04	0.04
16. Mesh feed gears..........	0.08	....	....	....	....
17. ROUGH TURN..........	....	....	....	....	....
18. Rapid travel head up..........	0.185	0.308	0.243	0.293	0.393
19. Rapid travel head back to end of rail normal..........	0.31	0.246	0.207	0.227	0.293
Total time to set and start first cut on outside diameter..........	1.94	1.94	2.25	2.60	3.50

* Length of run, ¼ inch.
† Length of run, 5/16 inch.
‡ Length of run, ⅜ inch.
¶ Length of run, ½ inch.

NOTE B: The time for setting tools for depth, for all first cuts, includes the time to move the ram from the normal position at the end of the rail and when the cut has been completed, to move it back again. When there are additional cuts to be made, the time for these includes the time to move the ram from the point of the finish of the first cut to the position of the second, and when it is completed, move it back to where the cut was started.

TABLE 17-*a*

Set and Tighten Tool in Tool Post, Manipulate Machine to Set Round-nose Roughing Tool for Depth and Start First Cut on Outside Diameter and Loosen and Remove Tool—Right-hand Head

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool in tool post, Table 13	0.28	0.35	0.37	0.40	0.43
2. Set tool for depth and start first cut on outside diameter, Table 17	1.94	1.94	2.25	2.60	3.50
3. Loosen and remove tool from tool post, Table 14	0.19	0.25	0.26	0.28	0.31
Total time	2.40	2.50	2.90	3.30	4.20

Refer to Note B under Table 17.

TABLE 17-*b*

Set and Tighten Tool in Tool Post, Manipulate Machine to Set Round-nose Roughing Tool for Depth and Start First Cut on Outside Diameter and Loosen and Remove Tool—Left-hand Head

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Set and tighten tool in tool post, Table 13-*b*	0.46	0.51	0.59
2. Set tool fo depth and start first cut on outside diameter, Table 17	2.25	2.60	3.50
3. Loosen and remove tool from tool post, Table 14-*a*	0.36	0.39	0.47
Total time	3.10	3.50	4.60

Refer to Note B under Table 17.

In compiling the tables it was discovered that certain items on large diameters ran smaller than the same items on smaller diameters. To counterbalance this seeming discrepancy there were other items that acted in the opposite direction. In con-

sequence there was very little difference between the total times for similar classes of work of large diameter and of smaller dimension. In fact, the percentage of the difference in times was so slight that no account need be taken of the variations. In consequence, two-thirds of the diameter of the boring-mill table has been chosen as the dimension of the work upon which to base the machine manipulation time tables in which the dimension of the work is a factor in the time required for the operation. This arbitrary selection of work diameter conforms to that of the usual run of work placed on the various sizes of boring-mill tables.

Throughout the tables no time has been allowed for stopping the machine. This time is included in the time after rough turning a space necessary for calipering, inasmuch as the tool continues to remove metal until the machine is stopped. Neither has any time been allowed for disengaging the feed and running the tool back as a separate operation after calipering. This item is included in the item "reset tool into work." When the proper diameter has been caught the feed is engaged and the machine operation proper begins.

It will be noted that the tables for "setting tools for depth to start cut" are made up in several forms, that is for the first cut and then for additional cuts. In the table for the first cut all the time that is required to bring the head over from the normal position, that is, from the end of the rail, and run it back after the cut has been made is taken care of. Also, in some of the first cut tables are included, in addition, unit times for setting the tools and tightening the tool post and the removal of the tool after the cut. These records make very useful tables, as such fundamental operations are quite general. In the tables for the additional cuts, time is allowed for the movement of the head to bring the tool into position to start the next cut. After this cut has been made an allowance is also made to bring the head back where it was when the cut was started. Tables split up in this manner are of great assistance in simplifying the writing of instruction cards. This matter will be referred to again in the description of how to use the tables in writing instruction cards and in predetermining the proper time to do a piece of work.

It is obvious that if a single cut is made the time for the first cut would be allowed for in the tables for the first cut, and if there are more than one cut the time for the cuts following the first will be found in the tables for additional cuts. The additional cut tables are usually made up in two forms: the

first form is where the operation for the additional cuts differs from the setting and starting of the first only in the movement of the head, as the distance of travel is only over to the place where the additional cut or cuts are to be started. In the second form the time for the additional cut is practically an allowance to move the head over to the new position to start a cut where no change is to be made in the dimension of the piece.

TABLE 17*A*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT IN A DIFFERENT PLANE ON THE OUTSIDE DIAMETER

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Length of Travel of Head in Inches				
	3	3	4	6	8
	Time in Minutes				
1. Rapid travel head to set next cut..	0.16	0.16	0.133	0.16	0.193
2. Start table....................	0.04	0.04	0.04	0.04	0.04
3. Set tool into work..............	0.18	0.19	0.21	0.26	0.34
4. ROUGH TURN piece for calipering (stop machine)................	*	*	†	‡	¶
5. Caliper.......................	0.21	0.22	0.23	0.28	0.42
6. Start table....................	0.04	0.04	0.04	0.04	0.04
7. Reset tool into work............	0.17	0.175	0.18	0.20	0.25
8. ROUGH TURN piece for calipering (stop machine)................	*	*	†	‡	¶
9. Caliper.......................	0.21	0.22	0.23	0.28	0.42
10. Start table....................	....	....	0.04	0.04	0.04
11. Reset tool into work............	....	....	0.18	0.20	0.25
12. ROUGH TURN piece for calipering (stop machine)................	....	....	†	‡	¶
13. Caliper.......................	....	....	0.23	0.28	0.42
14. Start table....................	0.04	0.04	0.04	0.04	0.04
15. Mesh feed gears (on 30-inch only) .	0.08	....	....	....	....
16. ROUGH TURN..................	....	....	....	....	....
17. Rapid travel head, to start of Item 1	0.16	0.16	0.133	0.16	0.193
Total time to set and start additional cuts on outside diameter.........	1.29	1.25	1.66	1.96	2.65

Refer to Note B under Table 17.
* Length of run, ¼ inch.
† Length of run, 5/16 inch.
‡ Length of run, ⅜ inch.
¶ Length of run, ½ inch.

TABLE 17*A-a*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT ON OUTSIDE DIAMETER IN THE SAME PLANE (MOVING HEAD DOWN TO NEXT CUT WITHOUT CHANGING THE DIAMETER SETTING)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Length of Travel of Head in Inches				
	3	3.5	4	6	8
	Time in Minutes				
1. Travel head down	0.16	0.16	0.133	0.16	0.193
2. Start table	0.04	0.04	0.04	0.04	0.04
3. Mesh feed gear (on 30-inch only)	0.08	....	....	....	....
4. ROUGH TURN	....	....	....	....	....
5. Travel head, to start Item 1	0.16	0.16	0.133	0.16	0.193
Total time to set and start additional cut on outside diameter in the same plane	0.44	0.36	0.31	0.34	0.43

Refer to Note B under Table 17.

In setting tools for and starting the first cut (Tables 17 and 17-*a* or 17-*b*) the manipulation similar to that for the first additional cut is necessary until the proper dimension is obtained in setting the tool, then the feed is thrown in and the cut started. It is assumed in the table listing the elementary operations involved and the respective unit times for the various acts (Table 17) that the diameter of the work is two-thirds that of the boring-mill table and that the down travel of the head for 30-inch mills is 4 inches; for 36-inch machines, 5 inches; for 42-inch, 6 inches; for 60-inch mills, 8 inches, and for the 84-inch class of boring mills, 12 inches. The rapid travels up are respectively the down travel of the head plus the width of the piece faced and an allowance of 2 inches for 30-inch machines; 3 inches for 36-inch mills; 4 inches for 42-inch; 6 inches for 60-inch, and 8 inches for the 84-inch type of boring mill.

In taking additional cuts (Tables 17*A* and 17*A-a*) it is assumed that they are taken before the tool head has been brought back to its normal position at the end of the rail. That is, the

rapid travel of the head is limited to that required to bring the tool into position to start the cut. On the average, the necessary movement of the head is equal to the diameter of the boring-mill table multiplied by the factor 0.01.

Three trials are allowed the workman to set the tool to the correct diameter for all sizes of machines, except the 30- and 36-inch mills, but this number is rarely necessary for expert workmen, particularly on duplicate work in large quantities. For expert manipulation, the items from 9 to 13 inclusive (Table 17*A*) may be omitted and the total time for the fundamental operation correspondingly reduced.

After a cut has been made, it is assumed that the boring-mill table is brought to a stop, but no time is allowed for stopping the table, as this is usually done during the cut and provision is made therefor in the machining time.

TABLE 17*B*

MANIPULATING MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON OUTSIDE DIAMETER

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over from normal position at end of rail......	0.31	0.246	0.207	0.227	0.293
2. Rapid travel head downward......	0.17	0.215	0.170	0.193	0.260
3. Start table....................	0.040	0.040	0.040	0.040	0.040
4. Set tool into work...............	0.150	0.160	0.170	0.200	0.240
5. FINISH TURN piece for calipering	*	*	†	‡	¶
6. Caliper cut (see Note *)..........	0.220	0.250	0.270	0.360	0.470
7. Start table.....................	0.040	0.040	0.040	0.040	0.040
8. Reset tool into work.............	0.150	0.050	0.160	0.180	0.210
9. FINISH TURN piece for calipering	*	*	†	‡	¶
10. Caliper cut (see Note *)..........	0.220	0.250	0.270	0.360	0.470
11. Start table.....................	0.040	0.040	0.040	0.040	0.040
12. Mesh feed gear (30-inch machine only).......................	0.08	......	......	......	......
13. Rapid travel head up............	0.185	0.308	0.248	0.293	0.393
14. Rapid travel head back to normal..	0.31	0.246	0.207	0.227	0.293
Total time to set tool to depth....	1.92	1.95	1.82	2.16	2.75

* Length of run, 3/8 inch.
† Length of run, 7/16 inch.
‡ Length of run, 1/2 inch.
¶ Length of run, 5/8 inch.
NOTE: The time for calipering given here is based on a piece whose diameter ist wo-thirds that of the table. For diameters which differ greatly from this figure consult the tables of calipering.
Refer to Note B under Table 17.

TABLE 17*B-a*

SET AND TIGHTEN TOOL IN TOOL POST, MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON OUTSIDE DIAMETER AND LOOSEN AND REMOVE TOOL—RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool in tool post, Table 13*A*	1.11	1.26	1.29	1.39	1.50
2. Set tool for depth and start first cut on outside diameter, Table 17*B*	1.92	1.95	1.82	2.16	2.75
3. Loosen and remove tool from tool post, Table 14	0.19	0.25	0.26	0.28	0.31
Total time	3.22	3.45	3.37	3.83	4.55

Refer to Note B under Table 17.

TABLE 17*B-b*

SET AND TIGHTEN TOOL IN TOOL POST, MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON OUTSIDE DIAMETER AND LOOSEN AND REMOVE TOOL—LEFT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool in tool post, Table 13*A-b*	These machines have but one head		1.39	1.50	1.66
2. Set tool for depth and start first cut on outside diameter, Table 17*B*			1.82	2.16	2.75
3. Loosen and remove tool from tool post, Table 14-*a*			0.36	0.39	0.47
Total time			3.60	4.04	4.88

Refer to Note B under Table 17.

Manipulating the machine to set the square-nose finishing tool for depth of cut and to start the first finishing cut on the outside diameter of the work (Tables 17*B* and 17*B-a* or 17*B-b*), including the removal of the tool, differs but in details from

the manipulation of the machine prior to starting the first rough cut on the outside diameter. The calipering trials do not have to be as numerous, for the work prior to the start of the finish cut has been calipered and the amount of metal to be removed on the finish cut is known. This reduces the time required for calipering, but certain of the other elementary operations are longer in the case of the finish cut than in the roughing cuts, so that the total time for the complete operation of setting the tool to depth is but little less, if any, in the case of the finish cut. The setting of the tool and tightening the tool post is a longer operation in preparing for a finish cut than when setting the round-nose tool, for greater care must be exercised to obtain an accurate setting.

Occasions arise when it is necessary to set the square-nose finishing tool for depth and start additional cuts on the outside diameter of a piece of work, but in a different plane than that of the first finishing cut, or in the same plane, but requiring a lowering of the turret head before commencing the cut. The elementary operations involved in such cases and their unit times are listed in Tables 17*C* and 17*C-a* respectively.

TABLE 17*C*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUTS IN A DIFFERENT PLANE ON THE OUTSIDE DIAMETER

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head to set next cut..	0.16	0.16	0.133	0.16	0.193
2. Start table....................	0.04	0.04	0.04	0.04	0.04
3. Set tool into work.............	0.15	0.16	0.17	0.20	0.24
4. FINISH TURN piece for calipering	....	....	....	....	....
5. Caliper.......................	0.22	0.25	0.27	0.36	0.47
6. Start table....................	0.04	0.04	0.04	0.04	0.04
7. Reset tool into work...........	0.15	0.15	0.16	0.18	0.21
8. FINISH TURN piece for calipering	....	....	....	....	....
9. Caliper cut....................	0.22	0.25	0.27	0.36	0.24
10. Start table...................	0.04	0.04	0.04	0.04	0.04
11. Mesh feed gears (only 30-in. machine).....................	0.08	....	....	....	....
12. Finish turn...................	....	....	....	....	....
13. Rapid travel head to start of Item 1	0.16	0.16	0.133	0.16	0.193
Total time to set and start cut....	1.26	1.35	1.27	0.15	0.67

Refer to Note *B* under Table 17.

TABLE 17C-a

Manipulate Machine to Set Square-nose Finishing Tool for Depth and Start Additional Cut on Outside Diameter in the Same Plane (Moving Head Down Without Changing the Diameter Setting)

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Travel head down	0.16	0.16	0.133	0.16	0.193
2. Start table	0.04	0.04	0.04	0.04	0.04
3. Mesh feed gear (on 30-inch only)	0.08	......	......	......	......
4. FINISH TURN	......	......	......	......	......
5. Travel head, to start of Item 1	0.16	0.16	0.133	0.16	0.193
Total time to set and start additional cut on outside diameter in the same plane	0.44	0.36	0.31	0.34	0.43

Refer to Note *B* under Table 17.

TABLE 17D

Manipulate Machine to Set Round-nose Roughing Tool for Depth and Start First Cut on Face of Work

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over *	0.38	0.246	0.207	0.227	0.293
2. Rapid travel head downward	0.17	0.215	0.17	0.193	0.26
3. Set tool for depth †	0.36	0.39	0.42	0.50	0.61
4. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11	0.12	0.12
5. Start table	0.04	0.04	0.04	0.04	0.04
6. Mesh feed gears (on 30-inch machine only)	0.08	......	......	......	......
7. Throw feed clutch in	......	0.05	0.05	0.06	0.07
8. ROUGH FACE (sto machine)	......	......	......	......	......
9. Loosen set screw that tightens vertical slide	0.11	0.11	0.11	0.12	0.14
10. Rapid travel head up	0.17	0.215	0.17	0.193	0.26
1 . Rapid travel head ov r to end of rail	0.355	0.338	0.28	0.327	0.43
Total time to set and start cut	1.78	1.72	1.56	1.78	2.24

Refer to Note *B* under Table 17.

*The 30-inch and 36-inch machines, the travel of the head and ram is done by cranking by hand. The cranking is a longer operation on the 30-inch machine than on the 36-inch. On the 42-inch and up the travel is by power. This accounts for the longer time of operation on the smaller machines.

TABLE 17*D*-*a*

SET AND TIGHTEN TOOL IN TOOL POST, MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOL FOR DEPTH AND START FIRST CUT ON FACE OF WORK, LOOSEN AND REMOVE TOOL—RIGHT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool on tool post, Table 13-*a*....................	0.28	0.28	0.30	0.33	0.36
2. Set tool for depth and start first cut on face of work, Table 17*D*......	1.78	1.72	1.56	1.78	2.24
3. Loosen and remove tool from tool post, Table 14*A*................	0.19	0.20	0.21	0.23	0.26
Total time......................	2.24	2.19	2.06	2.34	2.86

Refer to Note *B* under Table 17.

TABLE 17*D*-*b*

SET AND TIGHTEN TOOL IN TOOL POST, MANIPULATE MACHINE TO SET ROUND NOSE ROUGHING TOOL FOR DEPTH AND START FIRST CUT ON FACE OF WORK, LOOSEN AND REMOVE TOOL—LEFT-HAND HEAD

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	42	60	84
	Time in Minutes		
1. Set and tighten tool in tool post, Table 13-*c*.......	0.39	0.44	0.52
2. Set tool for depth and start cut on face of work, Table 17*D*..................................	1.56	1.78	2.24
3. Loosen and remove tool from tool post, Table 14*A*-*a*	0.31	0.34	0.42
Total time..................................	2.25	2.56	3.18

Refer to Note *B* under Table 17.

Facing work on the boring mill calls for a series of elementary operations which differ from those required for outside diameter work principally in that the cuts are taken in a horizontal, instead of vertical, plane. The operations necessary for setting tools and starting cuts, together with the unit time allowed

for each element, are listed in Tables 17*D*, 17*D-a*, 17*D-b*, 17*D-c* and 17*D-d*. The first of these tables refers to the acts incidental to setting the round-nose tool for depth and starting the first cut. The next two tables, 17*D-a* and 17*D-b*, give the detailed times required to loosen and remove the tool from the tool post for right-hand and left-hand turret heads respectively, while Tables 17*D-c* and 17*D-d* pertain to additional roughing cuts on other face surfaces or on face surfaces in the same plane, but necessitating the moving of the turret head from a position for one face surface to another position for another face surface between the operations of actually removing metal.

TABLE 17*D-c*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT IN A DIFFERENT PLANE OR SURFACE ON FACE OF WORK

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Length of Travel of Head in Inches				
	3	3.5	4	6	8
	Time in Minutes				
1. Rapid travel head over †	0.24	0.16	0.133	0.16	0.193
2. Set tool for depth *	0.36	0.39	0.42	0.50	0.61
3. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11	0.12	0.14
4. Start table	0.04	0.04	0.04	0.04	0.04
5. Mesh feed gears (on 30-inch machine only)	0.08	......	......	......	......
6. Throw feed clutch in	......	0.05	0.05	0.06	0.07
7. ROUGH ACE (stop mac ine)	......	......	......	......	......
8. Loose set scr w that tightens vertical slide	0.11	0.11	0.11	0.12	0.14
9. Rapid tra el head up	0.17	0.215	0.17	0.193	0.26
10. Rapid travel head back †	0.24	0.16	0.133	0.16	0.193
Total time to set and start cut	1.35	1.24	1.17	1.35	1.65

Refer to Note B under Table 17.

† In the 30-inch and 36-inch machines, the travel of the head and ram is done by cranking by hand. The cranking is a longer operation on the 30-inch machine than on the 36-inch. On the 42-inch machine and up, the travel is by power. This accounts for the longer time in operation on the smaller machines.

* By measuring with a scale from table of machine or by using a surface that has been set for height.

TABLE 17*D-d*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT IN THE SAME PLANE ON FACE OF WORK (MOVING HEAD OVER TO ANOTHER SURFACE)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over†	0.24	0.16	0.133	0.16	0.193
2. Start table	0.04	0.04	0.04	0.04	0.04
3. Mesh feed gears (on 30-inch machine only)	0.08	....	....	....	....
4. Throw feed clutch in	....	0.05	0.05	0.06	0.07
5. ROUGH FACE (stop machine)	....	....	....	....	....
6. Rapid travel head back *	0.24	0.16	0.133	0.16	0.193
Total time to set and start cut	**0.60**	**0.41**	**0.36**	**0.42**	**0.50**

* Refer to Note † under Table 17 *D-c*.
Refer to Note B under Table 17..

Manipulating the machine to set square-nose finishing tools for depth of final cuts on work faces and starting the cuts across the face surfaces necessitates a series of fundamental operations of the same general character. A wide range of work is made possible on Gisholt boring mills by the micrometer index dial by which the depth of cut may be rapidly and accurately set for the first cut on the face of the work or for additional cuts in different planes or surfaces on the face of the work. The micrometer index is particularly convenient in work entailed in repetitive manufacture.

Table 17*E* gives the elementary times for setting the finishing tool for a depth just sufficient to finish the face of the work; Tables 17*E-a* and 17*E-b*, the time for setting and tightening the tool in the post and removing it for right- and left-hand turret heads respectively; Table 17*E-c*, the time required to set the finishing tool in a different plane or surface on the face of the work, and Table 17*E-d*, the time for setting the tool for depth and starting an additional cut in the same plane—moving the head, without changing set of tool, from over one surface to another in the same plane. Tables 17*E-e* and 17*E-f* give time data for similar settings of the finishing tool for cuts across face surfaces by the micrometer index dial.

TABLE 17*E*

Manipulate Machine to Set Square-nose Finishing Tool for Depth and Start First Cut on Face of Work. Set Depth of Cut to Just Finish on the Face

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over*	0.38	0.246	0.207	0.227	0.293
2. Rapid travel head downward	0.17	0.215	0.17	0.193	0.26
3. Set tool for depth	0.12	0.12	0.13	0.14	0.17
4. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11	0.12	0.14
5. Start table	0.04	0.04	0.04	0.04	0.04
6. Mesh feed gears (on 30-inch machine only)	0.03	......	......	......	......
7. Throw feed clutch in	......	0.05	0.05	0.06	0.07
8. FINISH FACE	......	......	......	......	......
9. Loosen set screw that tightens vertical slide	0.11	0.11	0.11	0.12	0.14
10. Rapid travel head up	0.17	0.215	0.17	0.093	0.26
11. Rapid travel head over to end of rail	0.355	0.338	0.28	0.327	0.43
Total time	**1.54**	**1.44**	**1.27**	**1.32**	**1.30**

* Refer to Note † under Table 17*D-c*.
Refer to Note B under Table 17.

TABLE 17*E-a*

Set and Tighten Tool in Tool Post, Manipulate Machine to Set Square-nose Finishing Tool for Depth and Start First Cut on Face of Work—Right-hand Head

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool in tool post, Table 13*A-a*	1.11	1.12	1.15	1.25	1.36
2. Set tool for depth and start first cut on face of work, Table 17*E*	1.54	1.44	1.27	1.32	1.80
3. Loosen and remove tool from tool post, Table 14*A*	0.19	0.20	0.21	0.23	0.26
Total time	**2.83**	**2.76**	**2.63**	**2.80**	**3.42**

Refer to Note B under Table 17.

TABLE 17*E-b*

Set and Tighten Tool in Tool Post, Manipulate Machine to Set Square-nose Finishing Tool for Depth and Start First Cut on Face of Work—Left-hand Head

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Set and tighten tool in tool post, Table 13*A-c*....................	These machines have but one head		1.25	1.36	1.52
2. Set tool for depth and start first cut on face of work, Table 17*E*......			1.27	1.32	1.80
3. Loosen and remove tool from tool post, Table 14*A-c*..............			0.31	0.34	0.42
Total time......................			2.82	3.01	3.74

Refer to Note B under Table 17.

TABLE 17*E-c*

Manipulate Machine to Set Square-nose Finishing Tool for Depth and Start Additional Cut in Different Planes or Surfaces on Face of Work. (Set Depth to Just Finish on the Face)

Gisholt Boring Mills

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over.............	0.24	0.16	0.133	0.16	0.193
2. Set tool for depth.................	0.12	0.12	0.13	0.14	0.17
3. Tighten set screw that tightens vertical slide to head................	0.11	0.11	0.11	0.12	0.14
4. Start table......................	0.04	0.04	0.04	0.04	0.04
5. Mesh feed gears (on 30-inch machine only).......................	0.08	....	....	....	....
6. Throw feed clutch in..............	....	0.05	0.05	0.06	0.07
7. FINISH FACE (stop machine)...	....	....	....	....	....
8. Loosen set screw that tightens vertical slide.....................	0.11	0.11	0.11	0.12	0.14
9. Rapid travel head up.............	0.17	0.215	0.17	0.193	0.26
Total time......................	0.87	0.81	0.74	0.83	0.98

Refer to Note B under Table 17.

TABLE 17*E-d*

SET MANIPULATING MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUT IN THE SAME PLANE ON FACE OF WORK (MOVING HEAD OVER TO ANOTHER SURFACE)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over*	0.24	0.16	0.133	0.16	0.193
2. Start table	0.04	0.04	0.04	0.04	0.04
3. Mesh feed gears (on 30-inch machine only)	0.08	......	......	......	......
4. Throw feed clutch in	......	0.05	0.05	0.06	0.07
5. FINISH FACE (stop machine)	......	......	......	......	......
6. Rapid travel head back	0.24	0.16	0.133	0.16	0.193
Total time	0.60	0.41	0.36	0.42	0.50

* Refer to Note † under Table 17 *D-c*.
Refer to Note B under Table 17.

TABLE 17*E-e*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON FACE OF WORK. (SET DEPTH OF CUT BY MICROMETER INDEX DIAL)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over †	0.38	0.246	0.207	0.227	0.293
2. Rapid travel head downward	0.17	0.215	0.17	0.193	0.26
3. Set tool to depth by micrometer index dial	0.20	0.20	0.20	0.21	0.24
4. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11	0.12	0.14
5. Start table	0.04	0.04	0.04	0.04	0.04
6. Mesh feed gears (on 30-inch machine only)	0.08	......	......	......	......
7. Throw feed clutch in	......	0.05	0.05	0.06	0.07
8. FINISH FACE (stop machine)	......	......	......	......	......
9. Loosen set screw that tightens vertical slide	0.11	0.11	0.11	0.12	0.14
10. Rapid travel head up	0.17	0.245	0.17	0.193	0.26
11. Rapid travel head over to end of rail	0.355	0.338	0.28	0.327	0.43
Total time to set and start cut	1.62	1.52	1.34	1.39	1.85

* Refer to Note † under Table 17 *D-c*.
Refer to Note B under Table 17.

TABLE 17*E-f*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUT IN A DIFFERENT PLANE OR SURFACE ON FACE OF WORK. (SET DEPTH OF CUT BY MICROMETER INDEX DIAL)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
	Time in Minutes				
1. Rapid travel head over..........	0.24	0.16	0.133	0.16	0.193
2. Set tool to depth by micrometer index dial....................	0.20	0.20	0.20	0.21	0.24
3. Tighten set screw that tightens vertical slide to head.............	0.11	0.11	0.11	0.12	0.14
4. Start table......................	0.04	0.04	0.04	0.04	0.04
5. Mesh feed gears (on 30-inch machine only)..................	0.08	......	......	......	......
6. Throw feed clutch in............	......	0.05	0.05	0.06	0.07
7. FINISH FACE (stop machine)....	......	......	......	......	......
8. Loosen set screw that tightens vertical slide....................	0.11	0.11	0.11	0.12	0.14
9. Rapid travel head up............	0.17	0.215	0.17	0.193	0.26
10. Rapid travel head back..........	0.24	0.16	0.133	0.16	0.193
Total time......................	**1.19**	**1.05**	**0.95**	**1.06**	**1.28**

Refer to Note B under Table 17.

Table 17*F* gives the unit times for the fundamental operations necessary to manipulate the machine to set the round-nose roughing tools for depth of cut and to start the first cut on the outside diameter of the work when the turret simply has to be revolved to bring the roughing tool to position, the other turret stations being provided with suitable tools so that there need be no necessity of changing tools. Simple as is such machine manipulation, the total times given in the table are greater than in other tables for the setting of the same kind of tool and starting the cut where the gain is made by having the tools in holders ready to use. An allowance has to be provided for the time consumed to loosen, clamp, turn and tighten the turret. Additional cuts, when the turret is not revolved, take the times as given in preceding tables.

The manipulation of the machine to set round-nose roughing tools for depth and to start additional cuts on the outside

diameter of the work—the cutting tool in the turret head—(Table 17*F-a*) and that to set the roughing tool for depth and start additional cut on the outside diameter in the same plane, necessitating moving the head down to the additional cut without changing the diameter setting of the tool (Table 17*F-b*), entail elementary operations and unit times similar to those given in Tables 17*A* and 17*A-a* respectively.

The data presented in Table 17*G*—the unit times required to manipulate the boring mill to set either the round-nose roughing tool or the square-nose finishing tool for depth, to start a first cut on the outside diameter of the work, the cutting tools having been previously secured in the tool post—are for use only in repetition work and brings into use the micrometre index dial. The setting of the index dial is determined when the cut—roughing or finishing—is made on the first piece. For all subsequent pieces the desired cutting diameter is secured without trial or calipering by setting the tool to the recorded index dial reading. The various stations of the turret are assumed to be provided with the proper tools, so that the operating tool is brought to position by revolving the turret.

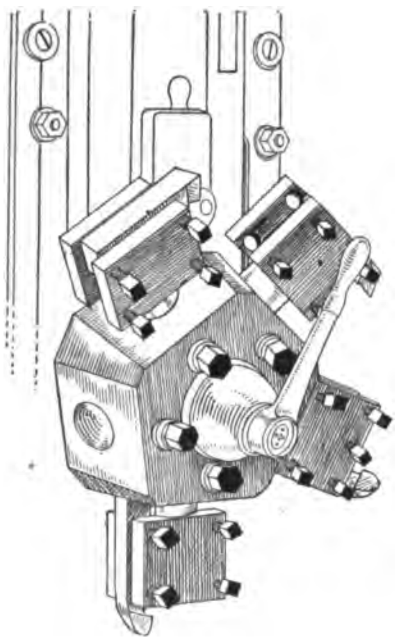


FIG. 50.—TURRET HEAD HOLDING FOUR TOOLS

Table 17*G-a* gives the detailed times incidental to the operations of manipulating the machine to set either the round-nose roughing tool or the square-nose finishing tool to depth and to start a cut on the outside diameter in the same plane, but removed in position from previous cuts. This necessitates lowering the turret head without changing the diameter of the tool setting and calls for elementary operations similar to those listed in Tables 17*A-a* and 17*C-a*.

TABLE 17*F*

MANIPULATING MACHINE TO SET ROUND-NOSE ROUGHING TOOL FOR DEPTH AND START FIRST CUT ON OUTSIDE DIAMETER—REVOLVE TURRET TO BRING TOOL TO POSITION

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp, turn turret and tighten	0.09	0.09	0.10
2. Rapid travel head over from end of rail (from normal position)	0.31	0.246	0.207
3. Rapid travel head down	0.17	0.215	0.170
4. Start table	0.40	0.04	0.04
5. Set tool into work	0.18	0.19	0.21
6. ROUGH TURN for calipering (stop machine)	*	*	†
7. Caliper (1)	0.21	0.22	0.23
8. Start table	0.04	0.04	0.04
9. Reset tool into work	0.17	0.175	0.18
10. ROUGH TURN for calipering (stop machine)	*	*	†
11. Caliper (1)	0.21	0.22	0.23
12. Start table	0.04	0.04	0.04
13. Mesh feed gears	0.08	....	....
14. ROUGH TURN	....	....	....
15. Rapid travel head up	0.185	0.308	0.243
16. Rapid travel head back to end of rail, normal	0.31	0.246	0.207
Total time	2.03	2.03	2.35

* Length of run, ¼ inch.
† Length of run, ⅜ inch.
Refer to Note B under Table 17.
NOTE: Turret tool posts are not used on machines larger than 42-inch except in special cases.

TABLE 17*F-a*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOL FOR DEPTH AND START ADDITIONAL CUT ON OUTSIDE DIAMETER (CUTTING TOOL IN TURRET HEAD)

GISHOLT BORING MILLS

REFER TO TABLE 17*A*

TABLE 17*F-b*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT ON OUTSIDE DIAMETER IN THE SAME PLANE (MOVING HEAD DOWN TO NEXT CUT WITHOUT CHANGING THE DIAMETER SETTING)

GISHOLT BORING MILLS

REFER TO TABLE 17*A-a*

TABLE 17*G*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING OR SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON THE OUTSIDE DIAMETER (REVOLVE TURRET TO BRING TOOL TO POSITION)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp, turn turret and tighten	0.09	0.09	0.10
2. Rapid travel head over from normal position	0.31	0.246	0.207
3. Rapid travel head downward	0.17	0.217	0.17
4. Start table	0.04	0.04	0.04
5. Set tool to depth by micrometer index dial	0.20	0.20	0.20
6. Mesh feed gears	0.08	......	......
7. Throw feed clutch in	......	0.05	0.05
8. TURN—ROUGH or FINISH	......	......	......
9. Rapid travel head up	0.185	0.308	0.243
10. Rapid travel head over to one side	0.31	0.246	0.207
Total time	1.39	1.40	1.21

NOTE: This table is to be used for repetition work. The setting of the index dial is determined when the cut is made on the first piece, and a note is made of it. For all succeeding pieces the desired diameter can be obtained without trial and calipering by setting to these readings.
Refer to Note B under Table 17.

TABLE 17*G-a*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING OR SQUARE-NOSE FINISHING TOOLS FOR DEPTH AND START CUT ON OUTSIDE DIAMETER IN THE SAME PLANE (MOVING HEAD DOWN WITHOUT CHANGING DIAMETER OF CUT)

GISHOLT BORING MILLS

REFER TO TABLES 17*A-a* AND 17*C-a*

NOTE: For additional cuts in different planes, it is necessary to have a tool in another turret post, or to have noted another setting of the index dial when the first piece was turned. In the first case, the time for setting the cut would be the same as in Table 17*G*, for in order to turn the turret the head has to be brought out to the end of the rail, and then back again.

The fundamental operations entailed in manipulating boring mills of the 42-inch class and smaller mills to set a square-nose finishing tool for depth and start a first cut on the outside diameter of the work when the turret stations are fitted with tools and the turret has to be revolved to bring the finishing tool into position, with the unit times for the various acts, are listed in Table 17*H*. Tables 17*H-a* and 17*H-b*—starting additional cuts on the outside diameter of the work, but in a different plane, and additional cuts in the same plane which necessitate

the lowering of the turret head—are similar to those already presented as Tables 17*C* and 17*C-a*.

TABLE 17*H*

MANIPULATE MACHINE TO SET SQUARE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON OUTSIDE DIAMETER, REVOLVING TURRET TO BRING TOOL INTO POSITION

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp, turn turret and tighten clamp	0.09	0.09	0.10
2. Rapid travel head over from end of rail	0.31	0.246	0.207
3. Rapid travel head downward	0.17	0.215	0.17
4. Star, table	0.04	0.04	0.04
5. Set tool into work	0.15	0.16	0.17
6. FINISH TURN enough to caliper	......	......	......
7. Caliper out	0.22	0.25	0.27
8. Start table	0.04	0.04	0.04
9. Reset tool into work	0.15	0.15	0.16
10. FINISH TURN enough to caliper	......	......	......
11. Caliper cut	0.22	0.25	0.27
12. Start table	0.04	0.04	0.04
13. Mesh feed gears	0.08	......	......
14. FINISH TURN	......	......	......
15. Rapid travel head up	0.185	0.308	0.243
16. Rapid travel over to one side	0.31	0.246	0.207
Total time to set and start cut	**2.01**	**2.04**	**2.02**

Refer to Note B under Table 17.

TABLE 17*H-a*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUTS IN A DIFFERENT PLANE ON THE OUTSIDE DIAMETER

GISHOLT BORING MILLS

REFER TO TABLE 17*C*

TABLE 17*H-b*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUT ON OUTSIDE DIAMETER IN THE SAME PLANE (MOVING HEAD DOWN WITHOUT CHANGING THE DIAMETER SETTING)

GISHOLT BORING MILLS

REFER TO TABLE 17*C-a*

Table 17*I* furnishes the necessary data as to required fundamental operations and their respective unit times, when the smaller sizes of Gisholt boring mills are manipulated to set round-nose roughing tools for depth to start a first cut on the face of the work—the tools held in a turret tool post. Manipulating the machine to set a round-nose tool for depth and start an additional cut on some face in a different plane—Table 17*I-a*—calls for the same fundamental operations and unit times as are given in Table 17*D-c*.

TABLE 17*I*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOL FOR DEPTH AND START FIRST CUT ON FACE (TOOLS HELD IN TURRET TOOL POST)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp turn turret and tighten	0.09	0.09	0.10
2. Rapid travel head over†	0.38	0.246	0.207
3. Rapid travel head downward	0.17	0.215	0.17
4. Set tool for depth*	0.36	0.39	0.42
5. Tighten set crew that tightens vertical slide to head	0.11	0.11	0.11
6. Start table	0.04	0.04	0.04
7. Mesh feed gears (on 30-inch machine only)	0.08	....	....
8. Throw feed clutch in	....	0.05	0.05
9. ROUGH FACE (stop machine)	....	....	....
10. Loosen set screw that tightens vertical slide	0.11	0.11	0.11
11. Rapid travel head up	0.17	0.215	0.17
12. Rapid travel head over to end of rail	0.355	0.338	0.28
Total time to set and start cut	1.86	1.80	1.657

* By measuring with a scale from table of machine or by using a surface that has previously been set for height.
† Refer to Note † under Table 17*D-c*.
Refer to Note B under Table 17.

TABLE 17*I-a*

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING TOOLS FOR DEPTH AND START ADDITIONAL CUT IN A DIFFERENT PLANE OR SURFACE ON FACE OF WORK

GISHOLT BORING MILLS

REFER TO TABLE 17*D-c*

The Tables 17*J*, 17*J-a* and 17*J-b* give the time data for setting square-nose finishing tools and starting cuts on the

face of the work when the tool is set to finish accurately the surface, when the tool is set in different planes and when the turret head has to be moved over to another surface in the same plane.

Finally, Table 17*K* lists the fundamental operations with their respective unit times for manipulating the machine to set round-nose roughing tools, square-nose finishing tools or any facing tools for depth when the tools are held in turret tool posts and the power feed is thrown in. This table is used for repetition work. The setting of the micrometer index dial of Gisholt boring mills is determined when the cut is made on the first piece, making trial or calipering for subsequent pieces unnecessary. For additional cuts in different planes, it is necessary to have a tool in another turret post, or have another setting of the micrometer index dial when the first piece is faced, following the procedure given in Table 17*E-f*. If a tool is in another turret post, the time for setting and starting the cut will be that given in Table 17*K*, for, in order to turn the turret head, it has to be brought out to the end of the rail, the turret turned and the head brought back again.

TABLE 17*J*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START FIRST CUT ON FACE OF WORK (SET DEPTH OF CUT TO JUST FINISH ON THE FACE), REVOLVE TURRET TO BRING TOOL TO POSITION

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp, turn turret and tighten	0.09	0.09	0.10
2. Rapid travel head over*	0.38	0.246	0.207
3. Rapid travel head downward	0.17	0.215	0.17
4. Set tool for depth	0.12	0.12	0.13
5. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11
6. Start table	0.04	0.04	0.04
7. Mesh feed gears (on 30-inch machine only)	0.08	......	......
8. Throw feed clutch in	......	0.05	0.05
9. FINISH FACE	......	......	......
10. Loosen set screw that tightens vertical slide	0.11	0.11	0.11
11. Rapid travel head up	0.17	0.215	0.17
12. Rapid travel head over to end of rail	0.355	0.338	0.28
Total time	1.63	1.54	1.37

* Refer to Note † under Table 17*D-c*.
Refer to Note *B* under Table 17.

TABLE 17*J-a*

MANIPULATE MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUT IN DIFFERENT PLANES OR SURFACES ON FACE OF WORK (SET DEPTH OF CUT TO JUST FINISH ON THE FACE)

GISHOLT BORING MILLS

REFER TO TABLE 17*E-c*

TABLE 17*J-b*

SET MANIPULATING MACHINE TO SET SQUARE-NOSE FINISHING TOOL FOR DEPTH AND START ADDITIONAL CUT IN THE SAME PLANE ON FACE OF WORK (MOVING HEAD OVER TO ANOTHER SURFACE)

GISHOLT BORING MILLS

REFER TO TABLE 17*E-d*

TABLE 17K

MANIPULATE MACHINE TO SET ROUND-NOSE ROUGHING OR SQUARE-NOSE FINISHING TOOLS FOR DEPTH AND IN GENERAL ANY TOOLS USED FOR FACING WHERE THE POWER FEED IS THROWN IN (TOOLS HELD IN TURRET TOOL POST)

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches		
	30	36	42
	Time in Minutes		
1. Loosen clamp, turn turret and tighten	0.09	0.09	0.10
2. Rapid travel head over*	0.38	0.246	0.207
3. Rapid travel head downward	0.17	0.215	0.17
4. Set tool to depth by micrometer index dial	0.20	0.20	0.20
5. Tighten set screw that tightens vertical slide to head	0.11	0.11	0.11
6. Start table	0.04	0.04	0.04
7. Mesh feed gears (on 30-inch machine only)	0.08	....	....
8. Throw feed clutch in	....	0.05	0.05
9. FACE, ROUGH or FINISH	....	....	....
10. Loosen set screw that tightens vertical slide	0.11	0.11	0.11
11. Rapid travel head up	0.17	0.215	0.17
12. Rapid travel head over to end of rail	0.355	0.338	0.28
Total time to set and start cut	1.71	1.64	1.44

* Refer to Note † under Table 17*D-c*.
Refer to Note B under Table 17.

On all facing cuts there is a clamping nut to tighten the ram, or up and down slide, after the desired dimension has been set. This nut must be loosened after the cut has been made.

The data submitted in Tables 17*F* to 17*K* apply to Gisholt boring mills of the 30-, 36- and 42-inch class only, as turret tool posts for the ordinary line of work are only found on machines up to and including the 42-inch size. For certain classes of work the turning tools remain in the turret for the whole time, so, when work has been clamped to the table it is only necessary to manipulate the turret to bring the tool into position for the cut that it is to make. The head is then rapid traveled over and down to a position to start the cut. The cut is started and the tool is set to depth according to the method illustrated in Table 17*K*, and the various operations of measuring are performed until the desired dimension is obtained, after which the rating on the micrometer index dial is noted if duplicate pieces are to be machined. At the completion of the cut the head is rapid traveled up and back. If cuts are to be made with the other tools the necessary manipulation of the turret is done to bring the next tool into position. The head is then rapid traveled over and down to a position to start the cut according to the method shown by the table for the desired kind of cut. If duplicate pieces are to be made the reading on the micrometer index dial is noted. At the completion of the cut the head is rapid traveled back. This procedure is continued until all of the tools in the heads are set, if this is required, or it is possible to set the same tool to several different dimensions by noting the readings on the micrometer index dial. It follows then that for cuts on duplicate pieces where the readings on the micrometer index dial have been noted the times are considerably shorter.

In a number of cases it is not necessary to allow time for setting and tightening tools in the turret tool posts and for removing them as this may be done while the cut is in progress. However, this practice is often accompanied with some danger and the saving of time does not warrant the risk.

The fundamental time tables here presented cover only a small portion and the most elementary of machine operations on Gisholt boring mills. In some shops it may be found that other combinations of fundamental operations would be useful. A careful study of the tables submitted will demonstrate clearly how they are built up and arranged and the same procedure can be followed in compiling tables for more special or complicated operations. It should be stated, however, that all tables should be carefully studied before attempting to make practical use of them or to compile new ones.

CHAPTER XI

MACHINING, LOOSING JAWS AND REMOVAL OF WORK

THE actual machining (removal of metal) is, of course, the ultimate objective of the preparatory work on all machine tools. The landing of the work, setting of the tools, manipulation of the machine to start cuts, and the various operations for which the elementary time tables presented in the preceding chapters list the necessary elements and unit times, form but incidental, though nevertheless, extremely important, aids as guides in the economic and efficient conduct of the work. Though it is true that it is in the performance of such preparatory operations that a considerable portion of the time consumed in a complete job on a boring mill, for example, may be spent—and not infrequently inefficiently spent, unless an approved standardized procedure is followed—the value of time study as a basis for rate setting is seriously discounted, if not made entirely valueless, unless machining operations are standardized so that the time actually consumed in removing metal can be accurately predetermined.

Standardization of machining operation does not constitute an actual part of time study work, but is rather a factor inseparable therefrom, upon which the value of time study may be said to depend. Removal of metal is a mechanical process which, barring accident, depends for effectiveness on the proper selection of cutting speed and feed, the characteristics of the metal to be machined, the depth of the cut, etc., considered in conjunction with the power of the machine. All of these elements should be standardized so that, with a knowledge of the machining processes to be performed on a given pieceof work, the time required for the operation to be efficiently performed can be accurately calculated. As in many cases of machining, the net machining time is the greater portion of the total time for the job, it is essential that it be possible to make such calculations with accuracy.

Dr. Frederick W. Taylor, in his published work, "The Art of Cutting Metals," gave to industry the invaluable secrets governing the machining of certain metals, the application of

which to the metal-working industry has been so extensively furthered by his co-worker, Carl G. Barth. Scientific time study presupposes a knowledge of the principles of metal cutting, when applied to the machine shop, and their commercial application. Unfortunately, many attempts are made at rate setting for machining operations in connection with which no adequate knowledge of metal cutting is available for application.

In time-study work for rate setting for machining operations all the aids and approved short cuts in calculating machining times, such as tabulated data, Barth slide rules for predetermining feeds and speeds, etc., should be employed. It may be assumed, therefore, that machine speeds and feeds have been standardized, the characteristics of the metal to be cut known—approximately, at least—and a knowledge possessed of all other factors necessary to establish accurate machining times. In making the necessary calculations, it must be remembered, however, that the length of the actual cut should be supplemented by that of the trial cuts that have to be taken in calipering or gaging and the necessary adjustment of the tool for the proper depth of cut, preparatory to the act of finally starting the correct cut. That is, in the case of a finishing cut on the outside diameter of work on a 30- or 36-inch boring mill which measures 8 inches in length, for example, the machining time should be figured for a cut of 8½ inches—the additional ½ inch being necessary for the two trial cuts for the calipering to set accurately the square-nose tool to depth. Under some conditions an allowance must also be made in connection with roughing cuts, because of roughness of work.

The task time for a specific job should include, furthermore, the time required to remove the work from the machine and this—in the case of Gisholt boring mills, at least—differs from that required to land the work on the boring-mill table. Before actually removing the work from the jaws of the chuck, or freeing it from the table, the chuck jaws, or the holding clamps, have to be loosened. Typical of the elementary operations entailed and the unit times involved for such operations are data listed in Table 19 for Gisholt boring mills of the 30-, 36-, 42- and 60-inch classes. The chuck jaw wrench has to be obtained from the tool tray, the jaws opened so the work may be removed and the wrench returned to the tray.

If the work can be handled by hand, which, if the piece is not of an unwieldly shape, can usually be done provided the piece weighs less than 80 or 100 pounds, the operation of removing the piece from the machine and placing in on the floor

calls for, on the average, a lift of about 3½ feet and a carry of some 6 feet or so. These arbitrary distances should approximately locate the position of the finished product on the floor, in reference to the normal position of the workman when at the machine, and were used in taking the time studies summarized in Table 19*A*. The data presented are applicable to the ordinary line of work conducted in an efficiently laid out shop, but if the conditions affecting the operation are abnormal, or the work has to be removed to some point considerably further from the machine, the unit times should be modified accordingly.

TABLE 19[1]

DETAIL TIME OF OPERATION TO LOOSENING JAWS TO REMOVE PIECE

GISHOLT BORING MILLS

Details of Operation	Size of Machine in Inches				
	30	36	42	60	84
Number of jaws loosened	1	1	1	2	....
1. Get chuck wrench from tray	0.035	0.04	0.045	0.06	....
2. Loosen jaws to remove piece	0.12	0.18	0.24	0.50	....
3. Remove wrench to tray	0.035	0.04	0.045	0.06	....
Total time to loosen jaws	0.19	0.26	0.33	0.66	......

Tools required: Chuck jaw wrench.

[1] The number 18 is omitted from the list of table numbers presented for the Gisholt boring mills as under such number could be classified the data pertaining to machining time.

TABLE 19A

DETAIL TIME OF OPERATION TO REMOVE PIECE FROM MACHINE TO FLOOR BY HAND

GISHOLT BORING MILLS

Details of Operations	WEIGHT IN POUNDS										
	5	10	20	30	40	50	60	70	80	90	100
1. Pick up piece from machine remove to floor six feet away	0.077	0.085	0.098	0.114	0.132	0.152	0.174	0.195	0.213	0.23	0.246

NOTE: In landing a piece on the table and removing it by hand, a man walks to the piece six feet from machine, lifts 3½ feet, returns six feet and lands it in the chuck jaws.

When the work is too heavy or cumbersome to be removed from the boring mill by hand, the use of a power hoist for handling the piece becomes advisable, if not absolutely necessary, just as in landing the work on the boring-mill table. Work pieces weighing more than 80 pounds entail such procedure, as a rule. The operation of removing the work from the machine, in such a case, calls for bringing a crane over the work, attaching the chain sling or other tackle, hoisting and removing

the work from the immediate vicinity of the boring mill and then removing the chain sling. Detail times for the fundamental operations involved, other than the time actually consumed in hoisting and removing the work, with a 10-ton Shaw electric traveling crane, are listed in Table 19*B*. In Table 19*B-a* summaries of the data in the preceding table together with the detail time for the actual hoisting and removing of pieces weighing from 90 to 1,250 pounds are listed. The tables are based on an average hoist of about 4 feet and a travel from the boring mill to the landing place on the floor of 15 feet. The studies were made with the use of a 10-ton Shaw electric traveling crane, but are as applicable to any other type of crane of similar hoisting speed and adequate power. Should cranes operated at other hoisting speeds be employed, it is only necessary to modify the unit times of the elementary operation of actual hoisting to make the time tables generally applicable—at least for all practical purposes.

In tracing the process of work on a Gisholt boring mill from the preparation of the machine to the removal of the work, the elementary time tables have been presented as nearly as possible in the sequence of the progress of the work, but in recording and classifying time-study data it is customary to group operations of similar nature, or operations which have

TABLE 19*B*

DETAIL TIME OF OPERATION TO SECURE CHAIN SLING ON PIECE TO HOIST AND REMOVE FROM MACHINE

GISHOLT BORING MILLS

Details of Operation	Weight in Pounds		
	To 150	Above 500	Above 1000
	Time in Minutes		
1. Call crane	1.50	1.50	1.50
2. Crane moved over work	0.20	0.20	0.20
3. Loop chains about work	0.43	0.62	0.74
4. Make chain sling taut	0.08	0.11	0.13
Total, securing rope to remove	**2.21**	**2.43**	**2.57**
5. Hoist and remove	See Table 19*B-a*		
6. Remove chains from about work	0.17	0.20	0.23
Total, removing chains after piece has been removed	**0.17**	**0.20**	**0.23**

TABLE 19*B*-*a*

DETAIL TIME OF OPERATION TO HOIST AND REMOVE PIECE TO FLOOR

GISHOLT BORING MILLS

Details of Operation	WEIGHT IN POUNDS											
	90	100	125	150	200	250	300	400	500	700	1000	1250
1. Secure chains to work (Table 19*B*).....	2.21	2.21	2.21	2.21	2.43	2.43	2.43	2.43	2.43	2.57	2.57	2.57
2. Hoist (about two feet) from chuck jaws..	0.07	0.07	0.07	0.07	0.071	0.072	0.073	0.074	0.075	0.082	0.096	0.11
3. Travel to pile (about ten feet).........	0.116	0.118	0.12	0.122	0.125	0.128	0.132	0.140	0.150	0.165	0.194	0.22
4. Lower and land piece on pile..........	0.077	0.078	0.079	0.081	0.083	0.086	0.090	0.096	0.105	0.116	0.138	0.16
5. Remove chains after piece has been removed to floor (Table 19*B*)......	0.17	0.17	0.17	0.17	0.20	0.20	0.20	0.20	0.20	0.23	0.23	0.23
Total time to hoist and remove piec. to floor..........	2.643	2.646	2.649	2.653	2.909	2.916	2.925	2.940	2.960	3.163	3.228	3.29
Total for practical use	2.60				2.95					3.20		

Tools required: 10-ton Shaw electric traveling crane or power hoist of equal hoisting speed

to be repeated in an opposite order, together in the same tables, or under one classification. For instance, the preparation of the machine to start work—landing the work, etc.—and the restoration of the machine to normal condition—removing the work, etc.—would come under one classification. The manipulation of the machine preparatory to commencing work and before various cuts, would be considered one class of work, and also the manipulation of the machine at the end of the cut. Clamping or otherwise holding the work and loosening and removing clamps would be similarly classified. Another class of operations would include both the setting of the tools preparatory to machining and the removal of the tools on completion of the cut.

The classification of time study data is a subject quite distinct from the taking of time studies, despite its close relationship, and will be taken up in an appendix following an example in the use of the elementary time tables derived from the machine studies on Gisholt boring mills.

CHAPTER XII

DEVELOPING A RATE FROM FUNDAMENTAL OPERATION TABLES

AN example in the use of Gisholt boring-mill elementary time tables for ascertaining the length of time that should be allowed to perform a specific piece of work, or job, will serve to demonstrate most effectively the approved procedure in the use of such time study data for practical purposes. It will also indicate a basis for a convenient classification more adaptable to working conditions than the arrangement of tables in the chronological order in which they were presented in the preceding chapters and afford an appropriate opportunity of explaining the approved form of instruction card.

Typical of the work suited to a boring mill, of a simple character, is the machining of a cast-iron bushing of 40-inch diameter, 8-inch face and 34-inch bore, the rough casting for which would weigh in the neighborhood of 1,000 pounds. There would be about half an inch of metal to be removed from each surface of the rough casting and the work would call for a machine of the 60-inch Gisholt boring-mill class. To machine such a piece four major operations would be required, dividing the work into two parts—1st, turning and facing one end of the bushing, and 2d, boring and facing the other end.

A standard form of instruction card for recording the instructions and time-study data is shown in Fig. 51, arranged for vertical filing, with an index of the task along the right-hand edge of the card and a tabulated summary of the time allowances, also at right angles to the body of the instructions, in the upper right-hand corner. The main body of the card is divided into a number of vertical columns for convenience in posting the time-study data. The first column is provided simply for the numerical indexing of the consecutive operations, or items, entailed, while the second column is reserved for the insertion of the unit times for the necessary tool setting and machine manipulation preceding and immediately following each machining operation. Then comes the wide column for the

detailed instructions, followed by three columns for the insertion of strictly technical information concerning the specific machining operations. The last two vertical columns are those in which are recorded the unit times for the various operations, as obtained from the Gisholt boring-mill tables. The first is for recording the unit times pertaining to preparation, cleaning machine, removing the work, dismantling and such other acts incidental to the job but not of a productive character, and the second column for all unit times involved in the actual production.

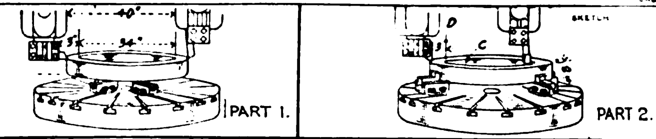
An analytical study of the detailed instructions for the scheduled items shows that they may be grouped to form, in their proper order, the twelve fundamental operations mentioned in Chapter VII as common to borning-mill work, with but one unimportant change made for greater convenience in compiling the instruction card. This variation consists simply in grouping the related fundamental operation combinations of setting tools and manipulating machine to start cuts and that of manipulating machine at end of cuts and removing tools under one general heading, "Manipulate machine to set and start," and placing this combination of four fundamental operations after the operation or operations of machining. The twelve fundamental operations are thus reduced to nine, as follows:

1. Preparing for work,
2. Landing work in machine,
3. Making work run true,
4. Securing work in machine,
5. MACHINING,
6. Manipulating machine to set and start cuts,
7. Loosening chuck jaws,
8. Removing work,
9. Restoring machine to normal condition.

As the job divides itself into two parts, the foregoing sequence of operations occurs twice, but for the acts of preparation and conclusion. The preparation—other than the necessary turning of the chuck jaws on commencing the second part of the work, landing the work within the reversed jaws and closing the jaws on the work—is limited to the first part of the job, while the conclusion—except for the removal of the work on the completion of the first part—occurs on the completion of the second part of the work. A few operations not fundamental to the preparation and production acts, the unit times for which are estimated or derived from experience, are listed as being essential, such as procuring job cards, etc., and cleaning the

INSTRUCTION CARD

ORDER No.



NO. OF ITEMS	TOOL SETTING AND MACHINE MANIPULATION	DETAILED INSTRUCTIONS	NO OF CUTS	FEED PER REVOLUTION	SPINDLE SPEED R P M	PREPARATION TIME IN MINUTES	UNIT TIME IN MINUTES
1		Change job card at window				2.50	
2		Return to machine				1.50	
3		Move rail from normal - 5-in (Table 2A)				2.98	
		PART 1. TURN OUTSIDE DIAMETER AND FACE ONE END					
4		Set chuck jaws to line (Table 6)				4.85	
5		Hoist & land piece in chuck jaws (Table 11A)					2.00
6		Make piece run true (Table 12)				6.35	
7		Tighten jaws on work (Table 12A)					1.52
8	(3.50) (1.96)	ROUGH TURN (A) 9 in. run (Tool PURC)	2	0.08	4.75		46.00
9	(2.34) (1.35)	ROUGH FACE (B) 3-3/4 in. run (Tool PURF)	2	0.08	4.75		
10	44.04	FINISH TURN (A) - 8-3/4 in. run (Tool PSFA)	1	0.375	3.35		6.80
11	2.80	FINISH FACE (B) - 3-1/2 in. run (Tool PSFA)	1	0.375	3.35		2.80
12		Manipulate machine to set and start cuts (Tables 17b-17A-17Da-17DC-17BB-&-17EA)					15.99
13		Loosen jaws (Table 19)					0.66
14		Hoist and remove piece (Table 19B-a)					3.20
15		Clean table (estimated)				5.00	
		TOTAL UNIT TIME					76.97
		55.60 Machine Time 5%					2.78
		23.37 Handling Time 28%					6.55
		TOTAL ALLOWED TIME, PART 1					86.30
		PART 2. BORE AND FACE OTHER END					
16		Turn chuck jaws end for end (Table 8)				6.68	
17		Hoist and land piece (Table 11A)					2.00
18		Make piece run true (Table 12)				6.35	
19		Tighten chuck jaws (Table 12A)					1.52
20	(3.30) (1.96)	ROUGH BORE (C) - 8-1/2 in. run (Tool PURC)	2	0.08	5.75		37.00
21	(2.56) (1.35)	ROUGH FACE (D) - 3-1/4 in. run (Tool PURF)	2	0.08	5.75		
22	3.63	FINISH BORE (C) - 8-1/4 in. run(Tool PSFA)	1	0.375	3.90		5.60
23	3.01	FINISH FACE (D) - 3-1/4 in.run (Tool PSFA)	1	0.375	3.90		2.40
24		Manipulate machine to set and start cuts, (Tables 17A-17A-17Db-17DC-17BA-&-17FB)					16.01
25		Loosen jaws (Table 19)					0.66
26		Hoist and remove piece (Table 19B-a)					3.20
27		Clean table (estimated)				5.00	
28		Move rail back to normal - 5 in. (Table 2A)				2.98	
29		Have job card signed				2.50	
30		Take job card to window to change jobs				1.50	
						48.19	
		Allowance 25%				12.06	
		TOTAL TIME ALLOWED FOR PREPARATION				60.25	
		TOTAL UNIT TIME					66.59
		45.20 Machine time 5%					2.26
		23.39 Handling Time 28%					6.55
		TOTAL ALLOWED TIME, PART 2					77.40
		TOTAL ALLOWED TIME, PART 1					88.30
		TOTAL TIME PER PIECE					165.70

MONTH	DAY	YEAR	SIGNED
11	2	1918	D.V.M.

BUSHING

Turn, face and bore

178-1

Cast Iron

1660 Lbs.

13

60" Gisholt Boring Mill 1 HY

1

FIG. 51—INSTRUCTION CARD FOR CAST-IRON BUSHING

boring-mill table on completion of each part of the job, but the necessity for their insertion is quite apparent.

The first two items, changing the job card, or ticket, and returning to the machine, are essentially preparatory in nature and have to be performed but once, so the unit times involved —their values established by experience and, obviously, subject to considerable variation in different shops—are entered in the preparation time column. The next act, moving the rail from normal, is also preparatory to the actual job and has to be performed but once, so its unit time—obtained from Table 2*A* of the Gisholt boring-mill data—is entered in the preparation time column.

The fourth of the listed items constitutes the real commencement of the actual job, but is also of the nature of preparation and being necessary but once, its unit time—obtained from the data tables—is entered in the preparation column. The landing of the work on the boring-mill table is a fundamental operation for each bushing, so the time entailed is placed in the unit-time column, where the unit times for all productively essential operations are posted. Making the piece run true is also a fundamental operation, but as the skillful operator could by suitable marks on the two chuck jaws, which have to be moved to remove the work, avoid the necessity of truing up subsequent pieces of similar dimensions, time for the act is required but once, so the necessary unit time is entered in the preparation time column. However, if very accurate turning were required and each piece machined had to be trued, the unit time for the act would be posted in the unit-time column.

The balance of the items listed for work on the first part are all fundamental to the work—with the exception of cleaning the boring-mill table—so their respective unit times are entered in the unit-time column. The various tables referred to in connection with the detailed instructions give, in each case, the source of the respective unit times.

The machining operations, Items 8, 9, 10 and 11, require for the determination of their respective unit times information as to the exact machine speeds and feeds to be used. A knowledge of the available power of the machine, the kind of material to be machined—its physical characteristics—and the cutting qualities of the tools to be employed is involved. The available power is particularly important in the case of roughing cuts. A standardization of machine tools, as suggested by Carl G. Barth, in a paper presented before the American Society of Mechanical Engineers in 1916, would greatly simplify the

determination of the times required for the machining operations, particularly if use is made of his slide rules for determining the correct speeds and feeds when the diameter of the work, depth of cut and the class of material to be cut is known. It is necessary to have calibrated the machine tool for speeds and feeds and tabulated the data for reference before it is possible to predetermine intelligently the time required to perform machining operations, in any event, but without standardization and the convenience of all approved aids for making computations the predetermination of machining times is made much more difficult. More time is required for the calculations, errors are more liable to occur and the full value of time study is not realized.

In the case of finishing cuts, the available power of the machine is of small moment, for there is sure to be sufficient power for such cuts, if the power is ample for the heavier roughing cuts. A knowledge has to be acquired, however, of the proper cutting speeds and feeds for the different kinds of tools employed and for the materials machined. Data may be determined by experiment, but to be reliable the investigations must be systematic and comprehensive.

The proper machine speeds and feeds for the various cutting operations, Items 8, 9, 10 and 11, determined, they are entered on the instruction card and the length of runs, or cuts, calculated and recorded, as shown. In figuring the run for roughing cuts, an allowance for undue roughness of casting is advisable, if not necessary, while for finishing cuts, it is necessary to allow trial cuts for calipering. Two roughing cuts are allowed and one finishing cut on each surface of the bushing, so the calculations for length of run are slightly involved. In the case of the two roughing cuts over the face of the bushing, one is necessary over the full face of the rough casting—9 inches plus any allowance for roughness—and the second over but about 8¾ inches, as before the second cut is started the face of the casting has been reduced by the thickness of the first rough facing cut. The mean run of the rough turning tool is then approximately 9 inches. In calculating the mean run of the rough facing tool, even more of an approximation is sufficiently accurate for practical purposes. The first rough facing cut is commenced after the first roughing cut on the diameter of the casting has been started—the thickness of the ring being less than the face of the casting—so its run is less than 4 inches, the thickness of the rough ring. Similarly, the second rough facing cut is commenced after the start of the second roughing turning cut, so

its run is not much more than 3½ inches. The mean length of run for the rough facing cuts may be taken as 3¾ inches, however, for all practical purposes. In the case of the finishing cuts, a ¼-inch trial run is added to the actual face of the partly machined bushing, making the finish cut run 8¾ inches, but no trial run is necessary for the facing tool, for any slight error can be corrected when facing the other end of the bushing. The lengths of the respective mean runs are entered on the instruction card, with the symbol of the particular tool to use in each case. With the length of runs determined and the correct feeds and speeds known, the unit times for the actual cutting operations are calculated and entered in the column of unit times.

The time values inserted in the column headed "Tool Setting and Machine Manipulation" are the unit times for such setting of the tool, manipulating the machine to start and at end of cut and removing the tool, as may be required for the respective cuts—the times obtained from the data tables. For the roughing cuts, two such entries are made as there are two cuts to be taken, but for the single finishing cuts one entry is sufficient. These tool setting and machine manipulating times are then added and their sum entered in the unit time column as the time for Item 12, "Manipulate machine to set and start cut."

The unit times for Items 13 and 14 are obtained directly from the data tables and entered in the unit time column, for they are fundamental to the work. Item 15, cleaning the boring-mill table, is a necessary but not essential act in the work. It is customary to make a time allowance for such cleaning but once for each part of the job, whether the job calls for one bushing or several, as the operator can clean off his boring-mill table without interfering with the steady progress of his work, if he has more than one bushing to machine. He would complete the first part of the work on all bushings before commencing the second part. The time for cleaning the boring-mill table is, therefore, inserted in the preparation time column.

The unit times for the various items constituting the second part of the work are obtained in a similar manner. The acts of preparation and conclusion of task differ, but the instructions for the various acts as given on the instruction card, with the references as to the source from which the unit times are obtained, should make the procedure quite apparent.

The column headed "Preparation Time" is totaled and a flat allowance of 25 per cent. added to give the time allowed for preparation. The column of unit times entailed in the actual

conduct of the work is also summed up for each of the two parts of the job. To the machine time included in the summations is added an allowance of 5 per cent. and to the handling time a percentage which is dependent upon its (handling time) proportion of the total time required for the job. This percentage is obtained from the allowance curves given in Fig. 4, Chapter II.

It will be noted that the handling time allowance for both parts of the job is the same, so that the unit time column could be summed up as a whole and the allowance added but once, instead of totaling the unit times for each part of the work and adding the same per cent. of allowance to each of the partial totals. The total result would be the same, but the division is regularly made, as if the job called for several bushings it would be necessary to know the task time for whichever part of the work the operator was working on, particularly if the job took several days to complete.

Reference to the allowance curves, Fig. 4, shows that for any job in which the time required to complete one piece is more than a quarter of an hour the percentage allowance for handling time, irrespective of what proportion it may be of the total time required for the job, lies between 24 and 32 per cent. The longer the work takes, per piece, the nearer the proper allowance comes to a mean value of 28 per cent., provided the time consumed in machining constitutes the major part of the total time consumed for the job. In fact, you might make a flat allowance of about 28 per cent. for handling time on all machine-tool jobs taking fifteen minutes or so to complete. In a shop where all jobs take considerable time, it may even be more convenient to increase the unit times recorded in the time tables by a fixed percentage and thereby avoid the necessity of adding a handling time allowance on the instruction card. If the preparation time constitutes but a small proportion of the total time for a job that takes an hour or longer to perform, the handling time percentage allowance may be reduced to 25 per cent., or the same as the per cent. added to the preparation time, so that all unit times may be increased by such proportion before entry on the instruction card. The addition of 5 per cent. to machine times can also be made before they are placed on the card and in this manner somewhat simplify the compilations, as well as the appearance of the instruction card.

APPENDICES

APPENDIX I

ORGANIZING A TIME-STUDY DEPARTMENT

APPENDIX I

ORGANIZING A TIME-STUDY DEPARTMENT

TIME-STUDY work, based, as it is, upon principles which cannot fail to be productive of material economic benefit to any establishment striving for sound, equitable and productive activity, must be handled in a systematic manner, if the objective is to be attained. No greater mistake can be made than to treat time study as of relatively minor importance or something to be attended to when there is nothing more pressing on hand. Nothing more pressing can be on hand, for the whole structure of industrial activity is built upon the conditions which it is the object of time study to standardize. No attention at all to time-study work is preferable to attempting to carry it on in a haphazard manner. A manufacturer might be able to do without time-study work, but to take it up and then drop it or sidetrack it for other work invariably entails a waste of money, dissatisfaction alike on the part of the workers and the management and subsequent decline in the efficiency of the establishment. Time-study work is evolutionary in nature. Its effects are frequently revolutionary, so it must be treated with due respect and accorded the importance it demands.

Even the smallest establishment offers sufficient time-study work to keep an expert observer busy for at least six months in taking studies and analyzing them, preparing instruction cards, setting rates, checking his investigations by production studies and indicating improvements in methods and tools that the time studies reveal as necessary. And after this work has been done, a trained executive is required—advisably the investigator himself—to put to effective use the data compiled and to continue similar investigations on new processes and developments. In larger establishments, the variety and volume of work may require the services of a large number of observers, etc., in which case it is advisable to effect a time-study departmental organization.

The work of a time-study department, whether it consists of one man or forty, comprises: (1) The taking of time studies;

(2) the analysis of these studies and the fixing of minimum times; (3) the determination of delay allowances for the several classes of work; (4) the setting of piece rates or tasks from the time studies; (5) the preparation of instruction cards, showing how the work can be accomplished within the time as determined by the time studies; (6) the taking of production studies to verify the time studies, or to discover errors in procedure on the part of the operators, or improper performance of the machines; (7) the discussion with the production or manufacturing department of improvements in tools and fixtures and of shop practice, that the time studies may show to be advisable.

Before beginning the time studies, a careful survey of the work of the establishment should be made to determine the character that the time study should assume; that is, whether the time-study department should devote itself to operation time studies or to fundamental operation studies, as defined in Chapter I and illustrated by specific examples in subsequent chapters, or to a combination of the two. In general, it may be stated that if the product consists of standard interchangeable parts, produced by a series of repetitive machine or hand operations, operation time studies will be indicated as most advisable. For example, typewriter and small-arms manufacture lend themselves admirably to operation time studies. On the other hand, if the product is of a variable character, few of the individual jobs entailing exactly the same operations, fundamental operation time studies will probably be productive of the most profitable results. Within this latter class will fall most machine-tool work, heavy foundry, the majority of large forging work and, in general, the greater part of operations calling for considerable power for their performance. If a product is in part standard and the remainder variable, it may prove profitable to begin with operation studies on the standard portion of the product. From these operation studies there will probably be available much machine data, which can later be supplemented by the necessary fundamental operation studies to give complete information regarding all the work that the factory will be called upon to do. The primary rule to be followed is that that work should be started first which will make the largest hole in the job. It is essential that the time-study department be made to pay for itself at the earliest practicable moment.

The time study should be under the direction of an engineer who has had considerable experience in this work. In the small

plant this engineer may represent the entire personnel of the department and he will take and analyze his own observations. In the plant with a time-study departmental organization he should make comparatively few observations himself, but should devote his energies to the training of his aids and to directing the work of the time-study men, who will take the time studies, analyze them and, from them, draw up instruction cards for the workmen. The studies should all be approved by the engineer, however, whose experience will enable him to judge of their accuracy and to decide upon the justice of the rates set from the observations. The engineer should also determine the character of the studies to be made—whether operation or fundamental—and lay out the schedule of studies so that they may be productive of profitable results as soon as possible. Prompt results will not only facilitate the engineer's work by securing the confidence of the management, but will win for him the co-operation of the workmen who are very apt to become interested in the work, instead of remaining antagonistic, as they are very frequently at first. The time-study man should be a man of broad experience and of keen insight.

Another of the duties of the time-study engineer is to make such revisions of methods and processes of manufacture as the time studies may show to be advisable. A case in point occurred in a plant engaged in the manufacture of one of the most important parts of a military rifle. The required production was so large as to exceed, it was thought, the capacity of the equipment employed for the work. At the end of five months, however, enough time-study observations had been taken and worked up to show that the required production could be obtained from the existing equipment by the correct manipulation of the machine speeds and feeds and by the proper rearrangement of the equipment. A further gain was then made by not allowing one man to operate more machines than he could consistently keep running.

At the time the studies were being taken a large number of machines were on order, but deliveries were delayed on account of the market conditions. As a result of the time-study work, it was possible to cancel orders for machines and fixtures which would have entailed an expenditure of close to a couple of hundred thousand dollars.

Prior to the time-study investigation the machines were arranged in groups of five or eight, each group operated by one man. The time study showed that two of the operations on the piece were unnecessary and that by changing the speeds and

feeds of all machines a considerably greater production could be obtained. In order to secure such increased production it was necessary to reduce the number of machines assigned to one operator and to regroup the machines. This was accordingly done, with the result that production was stimulated to the required amount—a quite material increase—and the operators, by following the newer instructions and procedure, succeeded in increasing their hourly earnings by about 60 per cent, doing so without increasing the severity of their tasks—in fact, by following the more approved procedure, their work was lightened. The workmen were well satisfied, obviously, the management was saved a very considerable expense for unnecessary equipment, and the desired production, which was the chief consideration at the time, was attained.

A more obvious example of the duty of a time-study engineer to make revision of methods and processes of manufacture would be in the case of a boring mill with two heads on a job where one head may be used conveniently for the rough turn on an outside diameter while the other head is used to take a rough facing cut on the upper surface of the work. In such a case it will frequently be found that the workman is in the habit of setting both tools before starting either of the cuts. It is often advisable to set one of the tools and start it cutting before setting the second tool and to start the second cut without stopping the machine—*i. e.*, while the first tool is actively employed removing metal. Time studies of the two methods show a considerable saving of time by starting one of the cuts before preparing for the other—when the dimensions of the work piece allow such procedure—and attending to the setting of the tool for the other cut while the first tool is being productively employed. The utilization of machining time, when the operator is comparatively freed from task, for preparatory operations and machine manipulations—when feasible—frequently offers opportunities for considerable saving of time and a corresponding increase in rate of production.

A time-study man should be proficient in the trade that he is to observe, though he does not necessarily have to be a skilled operator. It requires but a comparatively short time to train an intelligent man to take observations according to approved established methods. It does require, however, considerable judgment and experience on the part of the observer for him to know whether or not the operator is using the best methods and doing his work at his best average speed. Unless time studies are supplemented with such technical knowledge, they can be

of little real value—are, in fact, practically worthless. Men who have had the advantages of a college or technical school training, supplemented with some practical experience, make excellent time-study men, as a rule. Good mechanics, possessed of an analytical mind and a willingness to study, with the ability to examine closely into the merits of processes, also make first-class observers. These men who have been trained in the shops are usually particularly desirable for rating work for which the unit times are obtained from fundamental operation tables—*i. e.*, time-study data on fundamental operations classified in tabular form and available for predetermining rates on new work, or work of a similar character. Men of such caliber, after a year or two of time study, are fitted to take responsible positions in the production department, since their time-study experience will give them the most thorough knowledge of methods, rates and possibilities of the shop. The time-study engineer has few functions that are more important than the selection and training of these time-study observers.

In the shop where the time-study engineer is the entire time-study department he should at the earliest practicable moment decide upon and begin the training of his successor. The thoroughly competent time-study engineer is too valuable and should be too high-priced a man to be kept constantly at the taking and analyzing of observations. If he is to be a permanent part of the factory organization he should soon be graduated to a position of larger responsibility. If he is only temporary, and therefore more expensive, he should be enabled to organize the time-study work and train men to carry it on, so that he can be relieved and the expense of the work reduced as soon as possible.

The following is a description of the time-study organization of a factory employing several thousand hands and involving both wood and metal working. The department is under the direction of an engineer who gives his attention exclusively to it. He reports directly to the general superintendent and issues his instructions to the shop as to methods and rates through the production superintendents in charge of the several departments. An assistant, or time-study supervisor, reporting to the engineer, is in direct charge of the time-study observers and computers and is provided with a stenographer to assist him. The engineer decides, in consultation with the production superintendents, the studies that are to be taken and in conjunction with his assistant determines the sequence in which the work shall be carried out. The assistant assigns the studies

to the several observers, and the computation of them to the computer, and after analysis fixes upon the minimum selected times and the allowances as shown by the studies. He also, in conjunction with the engineer, determines finally the standard method for each job and draws up the instruction card for issuance to the shop.

The observer, after taking the time study assigned to him, turns his observation sheets over to the computer, who takes differences and so calculates the elapsed time for each elementary operation recorded. The observation sheets are then returned to the observer who, from knowledge he has acquired of the operation, eliminates from consideration all abnormal readings and who then hands the studies to the computer to determine averages, deviations and minimum selected times.

This work completed, the observer makes up the summary sheet that forms the basis of instruction cards. In making up this summary, unnecessary elements and false moves on the part of the workman that appear in the time study are eliminated, and the standard practice for the particular operation under study is formulated. Operations performed on a group of pieces are prorated to the individual piece at this time.

The summary as completed by the observer shows the selected minimum time of the operation. The time-study supervisor then takes the study in hand and checks it to make sure that deviations and minimum times are correct and that the standard of practice as laid down by the summary cannot be improved. Having satisfied himself as to these points, the supervisor adds the allowance for machine and personal delays, etc., and fixes a rate for the job. Next he causes the study of the operation to be repeated for a few cycles to assure himself of the correctness of all the previous work. This checking is quite practical in connection with operation studies, but it cannot always be done for rates set from fundamental operation studies. In such cases studies may have to be checked after rates set from them are in operation, and at times it may be necessary to make corrections in the rates. Verification of the study having been made, the supervisor passes the study to the time-study enginner for approval. Upon its approval by the engineer and also by the production superintendent of the department in which the study was taken, the summary is sent to the stenographer, who copies it in the form of an instruction card for the shop.

When rates are set from fundamental operation tables more dependence has to be placed on the man who makes up the

instruction card. Such a man should really be called a rate setter and must have had more experience in the trade under observation than would be required of an ordinary time-study man. Rates set from fundamental operation tables are usually for jobs of long cycles and of comparatively few pieces in a lot, so there is seldom any time during which a check could be taken. With a competent rate setter errors should be negligible, for any small error liable to occur forms usually such a small percentage of the task time that its effect would be unnoticed at the completion of all the pieces.

The rate setter should also be given authority to put into effect such rates as he may compile from rate tables and to make any necessary changes after they have been put into effect, reporting any such changes to the production superintendent.

A comprehensive and systematic method of noting, planning and recording the work of the time-study division forms naturally an important branch of the efficiently organized time-study department. An excellent system for keeping track of the work is employed in the same establishment drawn upon for an example of organized time-study procedure. At this plant the work is laid out and assigned to the various time-study observers by means of a planning box, or bulletin board, similar to that used for operators' job cards in the shop. The planning box consists of several groups of card pockets, three pockets to the group. These pockets are labeled respectively, "Jobs Ahead," "Observations Being Taken," "Observations Being Worked Up." One group of pockets is allotted to each man in the department, and in it, in the appropriate pocket, are placed the work cards of the various jobs assigned to him, these being transferred from pocket to pocket as the work progresses through the various stages.

In the "Jobs Ahead" pocket are placed the cards calling for studies of the operations on the different parts of the product. These cards are arranged in the pocket in the sequence in which the studies are desired, and by reference to them the time-study observer can tell exactly what work he is expected to do next. When he proceeds to take a study, he transfers the card from the "Jobs Ahead" pocket to the "Observations Being Taken" pocket. When the observations are completed, and the study is being worked up, the card is transferred to the third pocket, showing to the one in charge of the work that the study has been taken and that the computations are under way.

The work cards are ruled as shown in Fig. 52. The informa-

tion given by the card comprises the name of the part, the shop in which it is machined and the numbers of the operations, arranged in the sequence in which they take place. Reference to the progress sheets will inform the observer which of the operations on the part called for by any particular card are ready for time study. The observer fills in with pencil half of the space between the double lines at the top of the space imme-

21301 CAM SHAFT BEARING CAP GROUP E25AA									
1	2	3	4	5	6	7	8	9	10
11/6/16 11/7/16	11/7/16	11/8/16							

FIG. 52.—WORK CARD FOR RECORDING TIME-STUDY PROGRESS

diately below the operation number when he begins the study, and transfers the card to the "Observations Being Taken" pocket. (See operation 4, Fig. 52.) When the observations are completed, he fills in the remainder of the space between the upper double lines and writes the date below it. (See operation 3.)

Similarly, when the studies are being computed, the space between the lower set of double lines is half filled at the beginning of the work (see operation 2, second line), and completely filled in and the date written in above when the computation is finished. (See operation 1.)

At the end of the day all the cards representing jobs that were worked on during the day are deposited in a "Jobs Today" box. They are collected from this by the clerk and the progress of the work checked on the progress sheet, after which they are redistributed to the planning box, thus assigning the work for the following day.

The part-progress sheet that covers the work of the time-study observers and computers is shown in Fig. 53. One of these sheets is allotted to each part, and the various operations on that part are listed as shown. When a study is assigned to an

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PART PROGRESS SHEET ...1...SHEET — NO. 1

SHOP........................ DATE.................191...

PART... 21301 CAM SHAFT BEARING CAP GROUP R25AA

SIZE OF LOT ... 200

Time Observation Taken — Date	Time Observation Worked Up — Date	Instruction Card Prepared — Date	Instruction Card In Operation — Date	Oper-ation No.		Loca-tion	Mach. No.				Remarks
				1	Assem. Bushing to Cap	D3M	315V				
				2	Drill for Pins and Oil holes	D3M	10S				
				3	Pin Bushing and Ream	D3M	315V				
				4	Face and Turn Cap	D31M	21S				

FIG. 53. PART-PROGRESS SHEET

DEPARTMENT PROGRESS SHEET

Dept. #3 Checking Sheet DATE.................191...

Time Observation Taken — Date	Instruction Card In Operation — Date	Description of Part	Time Observation Made — Date	Instruction Card In Operation — Date	Description of Part
		21271 Fly Wheel Complete			
		21292 Trans. Brake Carrier Complete			
		21301 Cam Shaft Bearing Cap Group			
		21310 Carburetor Group			
		21312 Carburetor Needle Valve Division			

FIG. 54.—DEPARTMENT PROGRESS SHEET

observer on a particular operation, the space opposite that operation and between the double check lines entitled "Time Observations Taken" is filled half way down, as shown for "Operation No. 4, Face and Turn Cap," Fig. 53. When the time study has been taken, the rest of the space between the double lines and in line with the particular operation is filled in, as for operations 1, 2 and 3, Fig. 53. Similarly, when observations are assigned for computation, the fact is indicated by a half check—see operation No. 2, Fig. 53—which is completed when the observations are finished. The preparation of the instruction card and the act of putting it in force are similarly noted on the part-progress sheet, suitable double-line check columns being provided for that purpose.

These graphic entries are made on the part-progress sheet from information secured from the work cards that are filed in the planning board and should be kept up to progress, so that the progress sheets will show at a glance the condition of the time-study work on any part of the product. If all the operations on any part have been time-studied and instruction cards issued after computations and put into force, the several check columns on the particular part-progress sheet will be filled in. If only part of the operations have been studied, or only part of the observations computed, or if instruction cards remain to be drawn up and issued, a white space left in a check column will indicate instantly which operations remain to be studied, observations to be computed or instruction cards to be issued. Half-check marks show that work has been commenced on a time study, computation or instruction card, but not yet completed.

A somewhat similar record sheet is shown in Fig. 54, by which track is kept of the time-study work of a shop department. One or more such "Department Progress Sheets" are used for a single shop department. In the column entitled "Description of Part" are listed the names or symbols of the several parts manufactured in the department, each of which has its "Part-Progress Sheet," as illustrated in Fig. 53. As the time study is completed and the instruction card issued for any part, as shown by the check marks on the part-progress sheet, the corresponding checking is made opposite that part on the department progress sheet. Reference to Fig. 54 indicates that five parts are manufactured in Department No. 3, and for these the time study is complete and the instruction card has been issued for part No. 21,271, "Fly Wheel Complete," that the time study has been commenced for part No. 21,301, "Cam

Shaft Bearing Cap Group," and that nothing has been done in regard to the other three parts manufactured in the department.

In an establishment in which the majority of time studies are operation studies, as in the shop in which the record sheets just described are in use, the instruction cards for the shop are prepared directly from the summary sheets of the time studies. If the nature of the product is such that fundamental time studies would be better suited to the requirements of the establishment, the procedure followed in the time-study department should be somewhat different. The work should be laid out by the time-study engineer, as is customary, and the observations taken and computed in the same manner. The part-progress sheet, instead of indicating operations on a portion of the product, however, should list the fundamental operations that would be possible upon standard machine tools, such as a lathe, drilling machine, planer or boring mill. The time studies would be made and checked on the part-progress sheet exactly as would be the case were the observations operation time studies.

Data derived from studies, however, would be tabulated and filed according to the machine and to the class of work, and the instruction cards for the shop would be prepared from such tabulated and recorded data. In writing the instruction cards for use in the shops, the most marked changes in the personnel and duties of the time-study department would take place. The time-study organization would necessarily have to be increased by the addition of an expert mechanic, in the case of machine shops, who would possess to a high degree the ability to analyze shop drawings and to determine from them the best method of procedure to make the part called for. The duty of this man would be to reduce his analysis of the method of doing the work to writing, subdividing his instructions into as fine details as in his judgment would be considered necessary —*i. e.*, divide the operation into its elementary or fundamental operations, as the case requires. The method decided upon and the sequence of operations laid out, the time required for the performance of each of the acts entailed in the operation, as indicated, would be selected from the tabulated data and set opposite the respective elementary or fundamental operations. After totaling these items, the necessary allowances would be added and an instruction card drafted for the shop.

In a large shop there would be one or more rate setters who come under the supervision of the planning overseer, but who work in conjunction with the time-study division. The in-

formation for setting rates is supplied by the time-study division, whose duties, briefly stated, are to take time studies, write up instruction cards, compile elementary time tables for standard operations and furnish all unit times and standard feed and speed tables to the rate setters, to enable them to write instruction cards for the less frequently occurring jobs and to set the rates for the operatives.

There should always be, in addition to the rate setters, men who circulate among the operatives to assist them to carry out the directions given on the instruction cards and to report where the instruction cards seem in error and to need correction. These assistant overseers of production also set the speeds and feeds for the day work operatives.

APPENDIX II

CLASSIFICATION OF TIME-STUDY DATA

APPENDIX II

CLASSIFICATION OF TIME-STUDY DATA

TIME-STUDY department, even in an establishment conducting but a comparatively few simple operations in the production of a standardized product, will find it necessary to have on hand a pretty comprehensive amount of time-study data, if the business is to be conducted with the effectiveness and efficiency that should result from the progressiveness which proper time-study work will promote. The time-study records necessary for a product involving more numerous and more complex operations become exceedingly numerous, though the various elementary operations are few in number. In fact, there are but a comparatively few different elementary operations performed in any given trade, but there is a great number of combinations in which the few operations may be performed. As it is the totals of the unit times for the elementary operation combinations which are needed in setting rates for the conduct of the various acts incidental to the business, a comprehensive, but convenient, system of classification of time-study data becomes a question of considerable import.

Classification of time-study data must be comprehensive, for it is essential that the data pertaining to all combinations of elementary operations which may be within the scope of the business be available, or readily derived from the recorded observations. Classification must be according to some convenient system in order that any required information concerning combinations of elementary operations and their respective unit times may be found readily, without the necessity of a prolonged search. Otherwise, the value of the time-study department may be actually reduced by the very wealth of valuable data recorded but which is not readily available. The method of classification must be simple and capable of marked and orderly expansion as the time-study data accumulates, as it is bound to do in any establishment.

In the metal-working industry (machine shops) it has proved most convenient for the purpose of simplifying and shortening the instruction cards issued with a job to classify the data according to the fundamental operations involved, rather than

to attempt to keep fundamentals of different types of machines under a special classification. That is, it proves more convenient to classify time-study data according to its proper division of work than under the particular type of machine employed.

In machine-shop practice, almost any complete operation (a job, or division of work complete in itself) can be divided into twelve fundamental operations (a sequence of elementary operations entailed in the performance of some definite portion of a job) as follows:

1. Preparing the machine for the work, from a normal condition.
2. Landing the work in the machine, or in place.
3. Squaring and leveling the work to run true.
4. Clamping or otherwise holding the work in place
5. Setting the tools for the cuts.
6. Manipulating the machine to start a cut.
7. Machining, *i. e.*, removing metal.
8. Manipulating the machine at the end of a cut (reverse of No. 6).
9. Removing tools after completion of cuts (reverse of No. 5).
10. Loosening and removing clamps, etc. (reverse of No. 4).
11. Removing work, returning it to its original place (reverse of No. 2).
12. Restoring work place to its normal condition (reverse of No. 1).

This general division of a complete operation, arranged in the proper sequence of fundamental operations, should be followed in preparing the instruction cards for a standard machine operation and forms, therefore, a convenient and logical basis for the classification of time-study data.

For convenience in filing data pertaining to the various fundamental operations it is advisable to assign some arbitrary classification letter to the various fundamental operations under which to arrange the time-study data sheets, instead of attempting to classify the data under the number of the fundamental operation (the sequence number of the operation as listed in the division of a complete operation). Other letters may then be employed to designate miscellaneous classes of information correlated to time-study work; special data pertaining to gaging, measuring, calipering, etc.; standard process cycles, which are in themselves complete operations consisting of elementary operations occurring in definite sequence; rate tables, which are instruction cards in tabular form covering a complete class of work; and for various classes of machining.

Preceding this first letter a number may be used to designate a general class of work or a type of machine. This first number does not have to designate the same class of work or type of machine when used in combination with the various classification letters, but in various combinations may have different meanings. For example, the number *2* might designate a turret lathe when used in conjunction with the classification letter *N*, representing the fundamental operations of preparing the machine for the work or restoring the machine to its normal condition after the completion of a job, and something quite different when used with some other classification letter such as *P*, which might symbolize the operations of landing the work in place or of removing the work from the machine. That is, a time-study data sheet bearing the combined symbol *2N* would mean that it contained information concerning the time required to perform either of the fundamental operations involving the elementary operations necessary to prepare a turret lathe for a job or to restore it to normal condition, the two fundamental operations entailing the same elementary operations but in reverse order. A data sheet bearing the combined symbol *2P* on the other hand, would mean it covered information pertaining to the time required to land work in a machine, or to remove it, by some particular method.

Following the classification letter, a second number may be used to designate the number of the data sheet bearing a particular combination of classification letter and preceding number. To illustrate, if the letter *M* symbolized rate tables and the number *1* an engine lathe, the combined symbol *1M-5* would be carried by the fifth data sheet containing information pertaining to the time of a complete class of work performed on engine lathes. Another example, one which illustrates the scope of this method of classification when applied to the systematic arrangement of information not pertaining directly to time-study work, but correlated, would be a sheet bearing the combined symbol *1A-2*. If *A* designated miscellaneous information and the preceding number a description of the classification of time-study data, the combined symbol would identify the second sheet of the description of the classification of time-study data and indicate that the description was filed under miscellaneous information.

The filing of information and time-study data sheets according to this system of classification is extremely convenient and simple. The information is first filed under its classification letter, then under the number indicating the general class of

work or the type of machine and, finally, according to sheet or page classification in consecutive order. To locate any desired information, the procedure is to look under the "General Contents" for the classification letter of the fundamental operation or that designating a class of information correlated to time study work, then under the classification letter for the number symbolizing the general class of work or type of machine to be employed, and then find the page, or sheet, number preceded by the proper combination of classification letter and number representing the type of machine or general class of work on which is given the desired information. There can also be a cross reference arranged alphabetically.

This method of classification may be expanded readily to accommodate still greater index refinements. For instance, a second letter might be used to symbolize the elementary operations: such as *N* for "Loosen nut, lay down wrench." The letter should be the initial letter of the part entailing the elementary operation, while the preceding number and letter indicate the general class of work or type of machine and show the fundamental operation in which it could be used.

An approved form of "General Contents" according to such method of classification of time-study data would be:

GENERAL CONTENTS

Miscellaneous information	*A*
	B
	C
	D
	E
	F
Gaging, measuring, calipering, etc.	*G*
	H
	J
	K
Standard process cycles (complete operations with elements in definite sequence	*L*
Rate tables (Instruction Cards in tabular form covering a complete class of work)	*M*
Preparing machine for work or restoring it to normal condition (including such acts as changing job cards, getting tools, setting up machines, etc., and the reverse)	*N*
Landing work in place or removing work (including lifting the work by hand or hoist and moving it)	*P*
Squaring and leveling the work to make it run true	*R*
Clamping or otherwise holding the work securely and the loosening and removing of the clamps	*S*
Setting tools preparatory to taking a cut or removing the tools on completion of cut	*T*
Manipulating machine to start cut or at end of cut	*U*
Setting tools and manipulating machine to start cut, or manipulating machine and remove tools (a combination of *U*, *V*, and *G*)	*V*
Machining, removal of metal	*W*
	X
	Y
	Z

STANDARD PROCESS CYCLES 1-1-20

12" ENGINE LATHES

	G	N	P	S	T	U	W
	Gaging	Prep. Time	Land& Remove	Clamp Work	Set Tools	Manip. Mach.	Mach
1 Change card at window		2.00					
2 Get work and tools		5.00					
3 Run carriage up						.05	
4 Slide up tailstock and tighten						.10	
5 Turn up tailstock						.06	
6 Pick up piece fasten on dog				.06			
7 Land piece on centers			.04				
8 Turn up tailstock and clamp						.05	
9 Put tool in post, adjust and tighten					.15		
10 Put cutter in holder, tighten					.12		
11 Adjust tool (to height)						.10	
12 TURN							
13 Throw out feed, cutter back, move carriage to left						.035	
14 Gage (Mics)	.12						
15 Start spindle tool to depth, throw in feed						.06	
16 TURN							
17 Throw out feed, cutter back, move carriage to left						.035	
18 Gage (Mics)	.12						
19 Start spindle tool to depth, throw in feed						.06	
20 TURN							
21 Throw out feed, cutter back						.035	
22 Gage	.12						
23 Start spindle (tool at depth) feed in						.04	
24 Start spindle tool set for depth, feed in						.06	
25 TURN							
26 (Feed out) Run cross slide back						.03	
27 Move carriage to next cut, set tool for depth, feed in						.06	
28 TURN							
29 Feed out cross slide back, move carriage to next cut, Tool set to depth						.035	
30 CHAMFER							.035
31 Cross slide back, stop spindle						.06	
32 Remove cutter from holder					.12		
33 Remove tool from post					.10		
34 Loosen and remove piece			.04				
35 Loosen and remove dog				.06			
36 Move cross slide back						.06	
37 Loosen tailstock and slide back						.10	
38 Have card signed by foreman		1.50					
39 Return work and tools		1.50					

FIG. 55.—STANDARD PROCESS CYCLE

Many jobs on standard machine tools call for a sequence of operations, which, quite aside from the actual operations of removing metal, machining, become standard and may be termed "standard process cycles," the respective unit times for which are readily obtainable from properly classified time-study data. Comprehensive instruction cards for such jobs may be drawn up for any particular type and size of standard machine tool on which the unit times for the various elements, other than those involving actual machine operation, are entered. Such a standard process cycles instruction card, an initial development in classification of time study data, for a 12-inch engine lathe is shown in Fig. 55, the letters heading the various columns referring to the classification letters under "General Contents." The elements constituting the cycles, including the machine operations, are listed in consecutive order to the left of the form and to the right are provided columns for the various classes of operations in which the respective unit times are entered.

APPENDIX III

INSTRUCTION CARDS

APPENDIX III

INSTRUCTION CARDS

TO make practical use of time-study data in basing rates for the performance of work and establishing the correlated rate of payment for the task calls for a means by which the necessary instructions and the information needed by the workman to accomplish the task within the set time may be conveyed to him. These information mediums are termed "Instruction Cards" and are written instructions giving the sequence in which the elementary operations of a job should be performed, together with unit times allowed for the respective operations, the summation of which will give the total time for the job. The instruction cards should be written in as concise a form as possible and still convey clearly to the operator the procedure he should follow. Perspective sketches and simple drawings assist greatly in illustrating how the work should be done and, when feasible, should be made on the instruction card.

For work that entails but a few pieces of the same kind, or the consecutive repetition of a sequence of fundamental operations but a few times, it is important to impress the operator with the plan of procedure by which the rate was determined, so that the worker need lose no time in planning his work, thereby eliminating one cause for failure to equal the rate of production called for. In machine-shop work there may be number of elementary machining operations required for a job, each of which may call for a different machine speed and feed. Unless these feeds and speeds are specified on the instruction card the operator might easily fall behind schedule in his production through selecting less effective speeds and feeds or employing imprcper combinations. In manufacturing operations, where the same job is repeated day in and day out, instruction cards need be referred to but seldom once the operator has familiarized himself with the sequence of elementary operations and with the way to perform the fundamental operations most efficiently, but they form a valuable record of how the work should be done. They also serve as

important mediums for instructing new operators in the intricacies of the task and the best method of performing the work.

Though instruction cards are primarily mediums of instruction as to the approved method of procedure in performing a definite task, they cannot raise the unskilled worker to the plane of the skilled operator, so that workers should always be selected with a view to their skill along special lines. For machine-shop work entailing only operations on a few pieces of the same kind, a more highly trained operator is required than for work of a more repetitive character. Men who have served an apprenticeship at their trade or have had the training afforded in a good trade school should be selected. On manufacturing operations which are distinctly repetitive such training, though valuable, is not essential, for competent instruction, aided by comprehensive instruction cards, will make the workers quite proficient in a comparatively short time, if they have any mechanical aptitude at all.

Standard machine tools for all round machine-shop work, such as lathes, boring mills, planers, drilling machines, shapers, slotters, etc., require the services of a skilled operator who has served an apprenticeship or has had a trade-school training. The work for these machines lends itself to a very simple form of instruction card, as it follows a general sequence of fundamental operations, such as that discussed in the section devoted to time studies as applied to a line of machine tools, Gisholt boring mills.

As a matter of fact, any kind of work can be divided into similar fundamental operations and classified, but with more or less difficulty. For example, hand work on manufacturing operations and special machine work call for instruction cards which go into great detail as to elementary operations, unit times and processes. In these types of work two jobs are seldom similar enough to make any extensive use of classified data and it is necessary, therefore, to take a time study of each job for which a rate is required. Work done on standard machine tools and heavy foundry or forging work and similar tasks, on the other hand, favors the classification of fundamental operation data from which the time and rate of payment for any job can be predetermined and a comprehensive instruction card compiled from the recorded time-study data.

In almost any large plant there is sure to be a great variety of jobs that may be time-studied and for which rates should be set. Many of the jobs would require a different method of measuring the performance of the task than would be suitable

INSTRUCTION CARD — Order Number 6-6300 2/F (1)

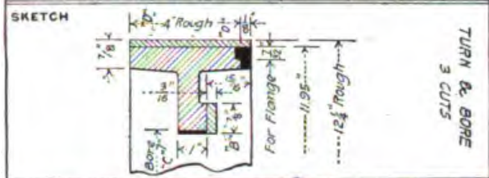
Name of Piece: WHEEL • SILENT

Description of Operation: SILENT WHEEL — 11.95" O.D. 3 11/16" FACE 60T — 9138 TURN & BORE (IN 3 CUTS)

First Mechanic: Base Rate 26¢; Per Piece 0.42; High Rate 14.8¢; Low Rate 12.3¢

O.D. Finish 11.95; O.D. Rough 12 1/4"; Face Finish 3 11/16"; Face Rough 4"; Bore 7"; Thickness 1"; Material C.I.; Class 19; Mach. No. 4T; Instr. Card No. 9138

Sketch:



No.	Detailed Instructions	Shape of Tool	Cuts No.	Cuts Depth	Feed Amount	Feed	Speed ft/min	Speed Symbol	Time Work Should Take
1	PUT WHEEL IN CHUCK & TIGHTEN								.48
2	START MACHINE, TURN TOOL HEAD, SET CUT TO FACE, FEED IN								.41
3	FACE "A"				0.0218		21.1		2.10
4	FEED OUT TOOL IN ABOUT 1" BY HAND								.15
5	SET TOOL BY SCALE ON SHEARS, IN 5/16" FOR "B" FACE FEED IN.								.30
6	FACE "B"				0.0218		24.7		1.80
7	RUN TOOL HEAD BACK								.09
8	RUN TURRET UP TO BORE, SET CUTTER, CENTRAL FEED IN								.30
9	BORE & TURN (ROUGH "D") 4 1/2" RUN						24.7		9.80
10	TOOL CARRIAGE BACK, STOP MACH., TURRET BACK								.24
11	START MACH. SET CUT FOR ROUGHING "D" SAME TOOL FEED IN								.26
12	TURN "D" FINISHING 4 1/4" RUN				0.0436		37.5		2.61
13	TOOL CARRIAGE BACK, TURN TOOL HEAD								.24
14	SET CUT FOR FLANGE								.20
15	TURN FOR FLANGE				0.006	HAND	21.1		1.70
16	TOOL CARRIAGE BACK (STOP MACH.)								.15
17	REMOVE WHEEL								.30
18	POWER FEED MACH TIME 16.91 - 10%; HAND " " " 1.70 - 25%								21.19; 1.69
19	HANDLING TIME								2.14
20	TIME IN MINUTES; " " HOURS								25.20; 0.42

When machine cannot be run as ordered machine boss must at once report to man who signed this slip. Month 10; Day 22; 1917

FIG. 56.—INSTRUCTION CARD FOR MACHINING CAST-IRON WHEEL

INSTRUCTION CARD — Order Number C8799 1/A (2)

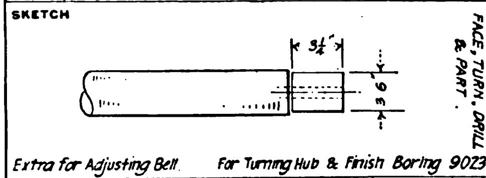
Name of Piece: WHEELS (BLANKS)

Description of Operation: FACE, TURN, DRILL & PART — 3/4 x 1 1/2 SC-16T — (9022) WHEN USING BELL CENTER

First Mechanic: Base Rate 26¢; Per Piece 225 HR.; High Rate 7.90; Low Rate 6.60
Second Mechanic: Preparation 0.1; 3.5; 2.90
Base Rate: Per Piece 0.237; 8.3; 6.90

O.D. Finish 3" 86; O.D. Rough 4.0; Face Finish 2 3/16"; Bore 1 1/2; Material BL. STOCK; Mach. No. 4T; Instr. Card No. 9022

Sketch:



Extra for Adjusting Bell. For Turning Hub & Finish Boring 9023.

No.	Detailed Instructions	Shape of Tool	Cuts No.	Cuts Depth	Feed Amount	Feed	Speed ft/min	Speed Symbol	Time Work Should Take
1	TURRET HEAD UP								.08
2	PUT SHAFT OUT 4"								.27
3	TIGHTEN CHUCK								.42
4	TURN TOOL TURRET, & RUN INTO CUT								.24
5	SET & START FACING CUT. & START MACH.								.26
6	FACE 1 7/8" RUN	PRSC			0.0105	a	88.0	1-C	2.10
7	RUN TOOL HEAD OUT, TURN TURRET & HEAD IN								.33
8	SET & START TURNING CUT								.20
9	TURN, ALSO DRILL (4" RUN)	PRBC	1/2 DRILL		0.0109	a	88.0	1-C	4.90
10	RUN TOOL HEAD OUT, TURN TURRET, & HEAD IN (SAME AS #7)								.33
11	SET & START CUT TO PART								.20
12	PART (ALSO REMOVE PINION BLANK)	PSCA	1 3/4" RUN		0.0105	a	632	9-B	2.50
13	TOOL HEAD BACK								.09
14	LOOSEN CHUCK JAWS								.18
15									11.51
16	MACHINE TIME 8.9 - 10%								.89
17	HANDLING TIME 2.60								1.30
18	MINUTES								13.50
19	HOURS								0.225
20									

When machine cannot be run as ordered machine boss must at once report to man who signed this slip. Month 10; Day 31; 1918; Signed Now

FIG. 57.—INSTRUCTION CARD FOR MACHINING SMALL WHEELS FROM BAR STOCK

for certain other jobs and the advisable method of rewarding the workers for their industry may also vary. This is probably best illustrated by examining a number of instruction cards that have been employed in a number of establishments where time study has been used as a basis for rate setting. Various types of instruction cards will be presented, all of which have been used in representative plants with excellent results in increasing production and decreasing costs. In every instance not only was there an increase in the amount of work done by the operators, but their earnings were increased, on the average, by 33⅓ per cent.—in many cases the increased earnings of the workers, due to their greatly stimulated output, was even more pronounced.

The first illustration, Figs. 56 and 57, are instruction cards employed at the Link Belt Company, Philadelphia, Pa., which are typical of instruction cards for operations on standard machine tools. Fig. 56 gives all the necessary detailed instructions for turning, facing and boring the cast-iron wheel shown in the sketch. A Gisholt turret lathe is used for the work and it will be noted that the instruction card does not list the elementary operations in their proper sequence and the unit times in which they should be performed. The unit times for elementary operations are placed in small figures above the items to which they apply, in order to condense the card as much as possible. The machine operations are lettered in somewhat bolder characters than the rest of the instructions, in order to make them more prominent and for each machining operation the exact feed and machine speed is stipulated. The unit times are totaled, the proper allowance added, and the sum of the unit times and the allowances gives the task time for the job.

Fig. 57 depicts the instruction card for facing, turning, drilling and parting small steel wheels from bar stock, also employing a Gisholt turret lathe for the work. The arrangement of the instruction card and the thoroughness with which it conveys to the worker the needed instructions for accomplishing the work in the time set does not differ from that of the instruction cards for machining the cast-iron wheels, except in so far as the elementary operations vary.

An important item of information borne by the two instruction cards and which should be entered on all instruction card setting rates of work is the rate of payment for the work and the monetary incentive offered for equaling or bettering the task time. At the Link Belt Company, for the type of work

covered by the instruction cards, the Taylor Differential Piece Work Plan of payment is in force. Under this plan the worker who succeeds in doing the work within the task time receives a piece-work rate, which is 35 per cent. more than the base rate for the work, while the worker who fails to complete the work in the task time receives a low rate, five-sixths of the high rate. The low rate is also a piece-work rate and, though considerably less than the high rate, is substantially higher than the base rate, or the amount which he would receive were he working on a day-work basis. The instruction cards carry the base rate for the work and also the high and low rates, expressed not in percentages or in total amounts, but in definite amounts as rewards, or premiums, to be awarded for the skill and industry displayed. The plan affords a powerful incentive for unusual effort on the part of the worker, for he has before him the exact reward he will earn for performing a reasonable task at a set and reasonable rate, if he follows an approved detailed procedure for which full instructions are provided. Furthermore, he can count upon a high rate of pay for all work completed in less than task time.

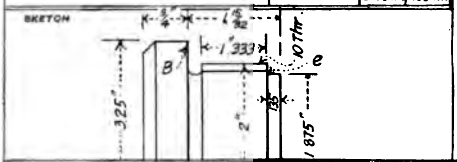
At the Link Belt Company, whenever one of these instruction cards is drawn up, a copy is filed for permanent reference and frequently reference is made to ascertain elementary times for operations of a similar character when making up instruction cards for other jobs. Or the instruction card in its entirety may be used for an analogous job, provided the instructions closely fit the conditions of the new work and the case is one which does not warrant the expenditure of the time necessary to make up a special rate for the new work.

The instruction cards shown in Figs. 58, 59, 60, 61, 62 and 63 are from the Watertown Arsenal, Boston, Mass., and were made up entirely from time-study data which had previously been collected, recorded and conveniently classified for use in making up instruction cards. It will be noted that opposite all handling-time items symbols are inserted which refer to the time-study data sheets from which the recorded unit times were obtained. The times indicated by the figures preceding the various machining operations are the unit times required to set the cutting tool and for the machine manipulation preparatory to starting the particular cut. All of these tool-setting unit times are summed up and the total entered in the right-hand column under the heading of setting tools. The calipering, or "try for size," unit times, the time allowed for loosening and removing tools, and other similar unit times for handling

8-18-14-1000 SF 30 AP CLASS OF WORK	DEPARTMENT	INSTRUCTION CARD	ORDER NO. 557-1	OPERATION: TURN & THREAD	NAME OF SYMBOL OR PIECE: SCREW

DESCRIPTION OF OPERATION		PREPARATION	TIME PER PIECE
	TIME WORK SHOULD TAKE	0.24 HR	1.0 HR
	TO EARN PREMIUM WORK MUST BE DONE IN		
	TIME BASIS	0.40 HR	1.66 HR

SKETCH



	DETAILED INSTRUCTIONS	SHAPE OF TOOL	CUTS No.	CUTS Depth	FEED Amount	FEED Symbol	SPEED R P M	SPEED Symbol	TIME IN Min.
1	Put piece in ⌀		(1D-5)						.32
2	1.44 ROUGH TURN A		2		.025	B8	56	lbs.	2.50
3	1.17 " FACE B		2		.020	HAND	"	"	1.40
4	Turn end for end	(Y-1D-5)							.38
5	1.17 FACE HEAD		2		.015	HAND	92	2BS	2.40
6	.80 CHAMFER					"	56	IBS	.60
7	Turn end for end		(Y-1D-5)						.33
8	1.17 FACE END		2		.015	HAND	92	IBS	1.50
9	1.44 FIN TURN A		2		.0166	B6	150	3BS	1.50
10	1.17 " FACE B		2		.070	HAND	92	2BS	1.60
11	.80 GROOVE FOR THREAD					"	"	"	1.00
12	.93 TURN C					"	"	"	3.50
13	File								3.00
14	Setting tools	(Y-1C-2-4-6)							10.00
15	Loosen & remove	(Y-1D-6)							.15
16									30.32
17	25% Machine time hand feed				12.00				3.00
18	10% " " power		"		4.00				.40
19	45% Handling time				14.32				6.45
20									40.17
21	Repeat #1								.32
22	4.19 THREAD		15		.100		40	4AS	10.00
23									
24									
25	Try for size	(Y-1C-9.1)							1.20
26	Setting tools	(Y-1C-9.1)							4.19
27	Loosen & remove	(Y-1D-6)							.15
28									15.86
29	10% Machine time		10.00						1.00
30	45% Handling time		5.86						2.64
31									19.50
34									
35									

DRAWING NO.	WEIGHT	O. D.	FACE	BORE	KIND OF MATERIAL	CLASS	MACH. NO. LOCATION	INSTR. CARD NO.
(A-10-3672)					STEEL		431ED4-4	8545

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD	MONTH	DAY	191	SIGNED

FIG, 58.—INSTRUCTION CARD FOR TURNING AND THREADING SCREW

INSTRUCTION CARD

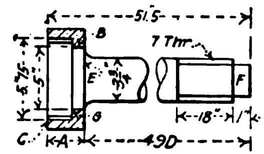
Department: D M

Order No.: 9321-43

Name or Symbol of Piece: SHAFT PISTON ROD

Operation: CENTER, TURN THREAD & SCREW ON PISTON TURN PISTON

Sketch



	Preparation Time	Time per Piece
Time work should take	1.50 HR	12.6 HR.
To earn premium work should be done in		
Time basis	2.50 HR	21.0 HR

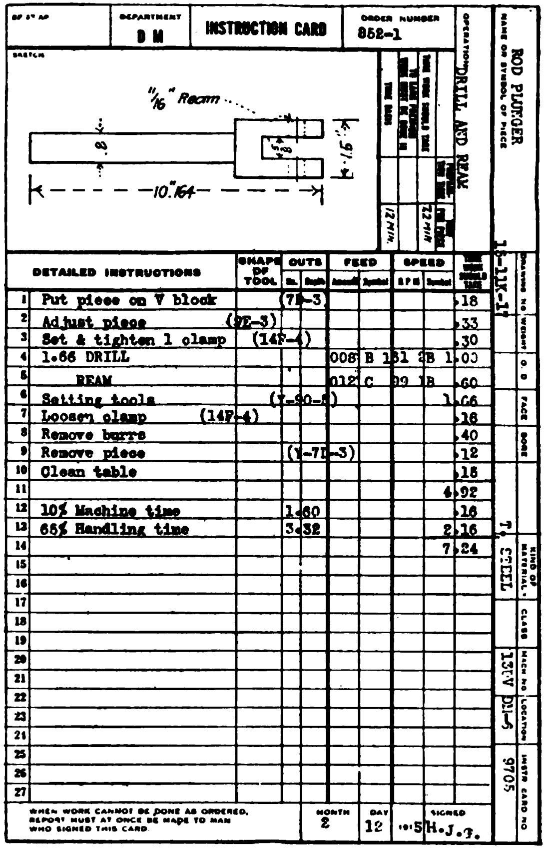
Drawing No.	Weight	O. D.	Face	Bore		Kind of Material	Class	Mach. No.	Location	Instr. Card No.
7-16-8J						F.S.#3		27LE	DM-4	8881

	Detailed Instructions	Shape of Tool	Cuts No.	Cuts Depth	Feed Amount	Feed Symbol	Speed R.P.M.	Speed Symbol	Time in Hrs.
1	Center both ends	(5659-1)							.500
2	Hoist & land piece in ℄ (Y-29-7)								.032
3	.0350 ROUGH TURN A		3	33	045	Hand	29	1BS	.200
4	.0290 " " B		2	2		"	"	"	.060
5	.0495 " FACE C		5	5	030	52CO	"	"	.375
6	Turn end for end (Y-2D-7)								.028
7	.0290 ROUGH TURN D		2	2	050	40RO	"	"	1.150
8	.0255 " CORNER					Hand	"	"	.100
9	.0285 " FACE END		3	3	030	52CO	"	"	.080
10	Setting Tools (Y-1C-3-4)								.196
11	Hoist & Remove (Y-2D-7)								.017
12									2.738
13	25% Mach. time hand feed			.100					.025
14	10% " " power	"		1.865					.196
15	30% Handling time			.773					.232
16									3.181
17									
18									
19	FIN TURN THREAD FOR AND FORCE ON PISTON								
20	Repeat #2								.032
21	.0367 FIN TURN D		2		.01566	4L	194	1CS1	.100
22	.0186 TURN F		2		"	"	"	"	.060
23	.0240 FACE END		2		0155	2RO	"	"	.070
24	File & Polish D								1.000

	Detailed Instructions	Shape of Tool	Cuts No.	Cuts Depth	Feed Amount	Feed Symbol	Speed R.P.M.	Speed Symbol	Time in Hrs.
26	Turn end for end (Y-2D-7)								.028
26	.0422 FIN TURN A		2		.01566	4L	142	2 BS	.080
27	.0367 " " B		2		"	"	"	"	.080
25	.0240 SQ. CORNER G		2		010	HAND	142	2BS	.075
26	.0185 FACE E		2		"	"	"	"	.060
27	.0133 RADIUS					"	"	"	.060
28	.0240 FACE C		2		015	52RO	"	"	.160
29	File								.150
30	Loosen ℄ & Put piston on rod & tighten ℄								.050
31	.070 THREAD		15		100		13	2AS	.400
32	Try for size & force on piston								.150
33	.0235 TURN O.D.		1		025	40L	94	1CS	.020
34	.0240 FACE		2		015	52RO	"	"	.040
35	.0240 FACE		2		"	"	"	"	.040
36	Setting Tools (Y-1C-5-6-9-9.1)								.385
37	Hoist & Remove (Y-2D-7)								.017
38									4.062
39	25% Machine time hand feed				.195				.049
40	10% " " power "				2.055				.205
41	30% Handling time				1.812				.544
42									4.860
43									
44	Repeat #3								.032
45	Close back rest & oil (Y-2L-1)								.008
46	.070 ROUGH THREAD		15		142		13	2AS2	.750
47	.048 FIN "		5		"		"	"	.950
48	Try for size								.150
49	Setting Tools (Y-1C-9.1)								.128
50	Open back rest (Y-2L-1)								.001
51	Loosen & Remove (Y-2D-7)								.017
52									4.036
53	10% Machine time	3.700							.370
54	30% Handling Time	.336							.100
55									4.521
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									

When work cannot be done as ordered report must at once be made to man who signed this card	Month	Day		Signed
	9	26	'4	H.J.G.

FIG. 59.—INSTRUCTION CARD FOR MACHINING A PISTON ROD SHAFT



INSTRUCTION CARD — DEPARTMENT: D M — ORDER NUMBER: 852-1

NAME OR SYMBOL OF PIECE: ROD PLUNGER
OPERATION: DRILL AND REAM

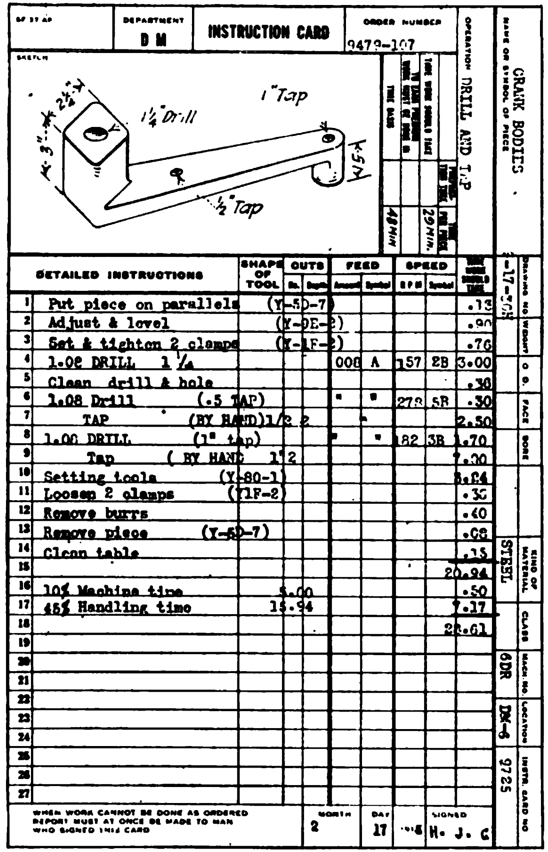
	PREPARATION TIME	TIME PER PIECE
TIME WORK SHOULD TAKE		22 MIN
TO EARN PREMIUM WORK MUST BE DONE IN		
TIME BASIS		12 MIN.

DRAWING NO	WEIGHT	O. D.	FACE	BORE	KIND OF MATERIAL	CLASS	MACH. NO	LOCATION	INSTR. CARD NO
15-11K-17					T, STEEL		13UV	DM-6	9705

	DETAILED INSTRUCTIONS	SHAPE OF TOOL	CUTS	FEED Amount	FEED Symbol	SPEED R P M	SPEED Symbol	TIME WORK SHOULD TAKE
1	Put piece on V block	(7D-3)						.18
2	Adjust piece	(9E-3)						.33
3	Set & tighten 1 clamp	(14F-4)						.30
4	1.66 DRILL			.008	B	131	3B	1.00
5	REAM			.012	C	99	1B	.60
6	Setting tools	(Y-90-5)						1.66
7	Loosen clamp	(14F-4)						.16
8	Remove burrs							.40
9	Remove piece	(Y-7D-3)						.12
10	Clean table							.15
11								4.92
12	10% Machine time		1.60					.16
13	65% Handling time		3.32					2.16
14								7.24
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								

WHEN WORK CANNOT BE DONE AS ORDERED, REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD. — MONTH 2 — DAY 12 — 1915 — SIGNED H. J. G.

FIG. 60.—INSTRUCTION CARD FOR DRILLING AND REAMING A PLUNGER ROD



INSTRUCTION CARD — DEPARTMENT: D M — ORDER NUMBER: 9479-107

NAME OR SYMBOL OF PIECE: CRANK BODIES
OPERATION: DRILL AND TAP

	PREPARATION TIME	TIME PER PIECE
TIME WORK SHOULD TAKE		29 MIN.
TO EARN PREMIUM WORK MUST BE DONE IN		
TIME BASIS		48 MIN

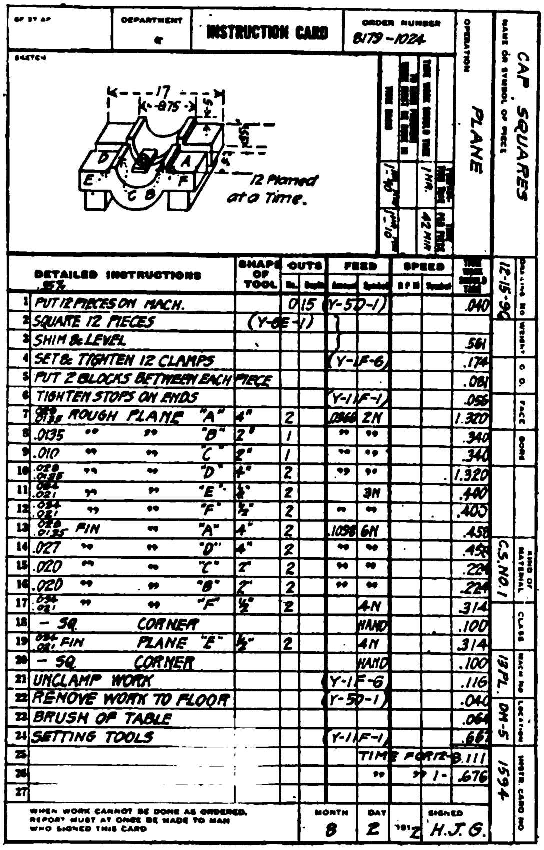
DRAWING NO	WEIGHT	O. D.	FACE	BORE	KIND OF MATERIAL	CLASS	MACH. NO.	LOCATION	INSTR. CARD NO
-17-30					STEEL		6DR	DM-6	9725

	DETAILED INSTRUCTIONS	SHAPE OF TOOL	CUTS	FEED Amount	FEED Symbol	SPEED R P M	SPEED Symbol	TIME WORK SHOULD TAKE
1	Put piece on parallels	(Y-5D-7)						.13
2	Adjust & level	(Y-9E-2)						.90
3	Set & tighten 2 clamps	(Y-1F-2)						.76
4	1.02 DRILL 1 ¼			.008	A	157	2B	3.00
5	Clean drill & hole							.30
6	1.08 Drill (.5 TAP)			"	"	278	5R	.30
7	TAP (BY HAND) 1/2 2							2.50
8	1.00 DRILL (1" tap)			"	"	182	3B	1.70
9	Tap (BY HAND 1" 2							7.30
10	Setting tools	(Y-80-1)						3.84
11	Loosen 2 clamps	(Y1F-2)						.36
12	Remove burrs							.40
13	Remove piece	(Y-5D-7)						.08
14	Clean table							.15
15								20.94
16	10% Machine time	5.00						.50
17	45% Handling time	15.94						7.17
18								28.61
19								
20								
21								
22								
23								
24								
25								
26								
27								

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD — MONTH 2 — DAY 17 — 1915 — SIGNED H. J. G

FIG. 61.—INSTRUCTION CARD FOR DRILLING AND TAPPING CRANK BODIES

operations are also totaled and entered in the right-hand column for convenience in separating handling times from machine times in calculating the necessary delay allowances. Instruction cards Figs. 58 and 59 are for work on engine lathes; those shown in Figs. 60 and 61 are for operations performed on vertical drilling and radial drilling machines respectively; that given as Fig. 62 covers a job on a planer; and the instruction card illustrated in Fig. 63 is for a long job on a floor-boring machine. This last instruction card is unique in the length of time required to perform a single piece task, 117.5 hours. These six illustrations of instruction cards employed at the Watertown Arsenal are good examples of instruction cards for machine-tool operations, written as concisely as is practical and still conveying a clear idea of the plan on which they were made up.



	DETAILED INSTRUCTIONS .95%	SHAPE OF TOOL	CUTS No.	CUTS Depth	FEED Amount	FEED Symbol	SPEED F.P.M.	SPEED Symbol	TIME WORK SHOULD TAKE
1	PUT 12 PIECES ON MACH.		0	15	(Y-5D-1)				.040
2	SQUARE 12 PIECES	(Y-6E-1)							
3	SHIM & LEVEL								.561
4	SET & TIGHTEN 12 CLAMPS				(Y-1F-6)				.174
5	PUT 2 BLOCKS BETWEEN EACH PIECE								.081
6	TIGHTEN STOPS ON ENDS				(Y-1F-1)				.056
7	.028 .0135 ROUGH PLANE "A"	4"	2		.0866	2N			1.320
8	.0135 " " "B"	2"	1		"	"			.340
9	.010 " " "C"	2"	1		"	"			.340
10	.028 .0135 " " "D"	4"	2		"	"			1.320
11	.034 .021 " " "E"	½"	2			3N			.400
12	.034 .021 " " "F"	½"	2		"	"			.400
13	.028 .0135 FIN " "A"	4"	2		.1096	6N			.458
14	.027 " " "D"	4"	2		"	"			.458
15	.020 " " "C"	2"	2		"	"			.224
16	.020 " " "B"	2"	2		"	"			.224
17	.034 .021 " " "F"	½"	2			4N			.314
18	– SQ. CORNER					HAND			.100
19	.034 .021 FIN PLANE "E"	½"	2			4N			.314
20	– SQ. CORNER					HAND			.100
21	UNCLAMP WORK				(Y-1F-6)				.116
22	REMOVE WORK TO FLOOR				(Y-5D-1)				.040
23	BRUSH OF TABLE								.064
24	SETTING TOOLS				(Y-1F-1)				.667
25						TIME FOR 12			8.111
26						"	" 1 -		.676
27									

WHEN WORK CANNOT BE DONE AS ORDERED, REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD | MONTH 8 | DAY 2 | 1912 | SIGNED H.J.G.

FIG. 62.—INSTRUCTION CARD FOR PLANING CAP SQUARES

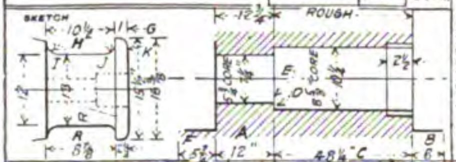
At the time these cards were made up and other instruction cards to be presented as illustrations from the same plant the method of payment-rate setting at the Watertown Arsenal was according to the Halsey Premium Plan. This method of regulating the earnings of the workers according to the skill and industry displayed in performing their tasks will be described in some detail in a section devoted to rating methods and wage systems.

8-28-14-1000 ST 66 AP CLASS OF WORK	DEPARTMENT	INSTRUCTION CARD	ORDER NO 4580 - 1390

OPERATION	NAME OR SYMBOL OF PIECE
TURN TRUNIONS & BORE CYLINDERS	CRADLE 12" MORTAR

DESCRIPTION OF OPERATION		PREPARATION	TIME PER PIECE
	TIME WORK SHOULD TAKE	300 HR	117.5 HR
	TO EARN PREMIUM WORK MUST BE DONE IN		
	TIME BASIS	5 00 HR	196 HR

SKETCH



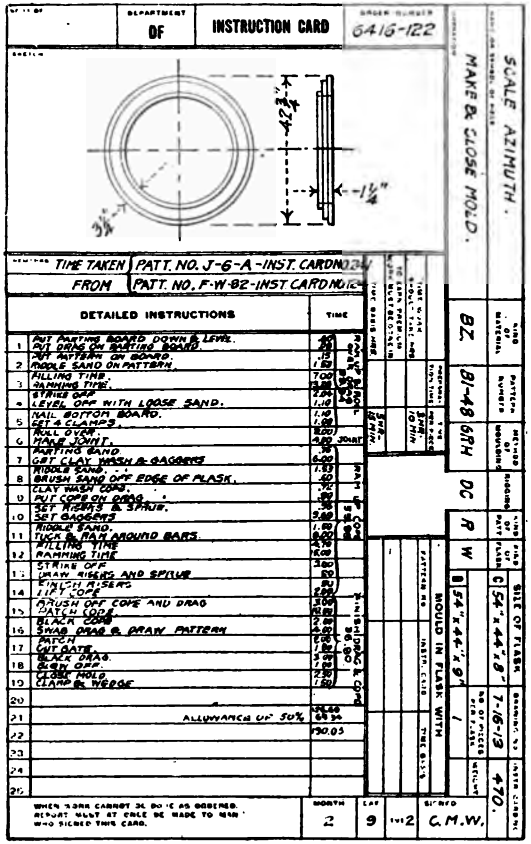
	DETAILED INSTRUCTIONS	SHAPE OF TOOL	CUTS No.	CUTS Depth	FEED Amount	FEED Symbol	SPEED R P M	SPEED Symbol	TIME IN
1	PUT ON MACHINE STRAP DOWN								1 40
2	LINE UP BY BAR								1 00
3	SETTING TOOLS								1 82
4	.01 ROUGH BORE 1ST TRUN. 5" RUN	PRSC	2		0 0125	3A	13 75	5A	.90
5	.01 " " 2ND " "	PRSB	2		0 0125	3A	13.75	5A	.90
6	RELINE UP BAR BY WORK								.50
7	.04 FINISH BORE 2ND TRUN. 5" RUN	PRSB	1		0 0206	4A	"	"	.28
8	.04 " " 1ST " "	PRSC	1		0 0206	4A	"	"	.28
9	PUT 2 SMALL FACING HEADS ON BAR								.20
10	0.25 0.25 XB ROUGH FACE (BOTH TRUN) 5" RUN	SPECIAL	7		0.025	[illegible]	7 30	3A	3 57
11									
12	REMOVE 2 SMALL FACING HEADS								.26
13	PUT 2 BUSHINGS IN BORE								.40
14	PUT ON LARGE FACING HEAD								.13
15									
16	.06 ROUGH TURN "B" 3" RUN		1		0.02	4A	54	2A	.50
17	.053 " " "H" (RISER) 5" RUN		3		0.02	4A	7.3	3A	1 87
18	.053 " FACE "J" 3" RUN		3		0.0416	[illegible]	"	3A	.56
19	.03 " TURN "H" 10½ "		2		0.02	4A	"	"	2 61
20	.02 HEAD BACK ON SIDE I 4" .02 SET CUT, ROUGH FACE		6		0.0416	[illegible]	54	2A	1 95
21	.02 FINISH FACE "I" 4"		2		"	"	"	"	.66
22	.053 " " "J" 3"		1		"	"	"	"	.94
23	.06 " TURN "H" 10½ "		1		0.0082	2A	"	"	4 40
24	.02 " FILLET J 25%				HAND		"	"	.56
25	.02 FINISH FILLET 25%				HAND		54	2A	.56
26	.06 " TURN "G"		1		0.02	4A	"	"	.44
27	.05 " FACE "K" 4½ RUN		3		0.0416	[illegible]	"	"	1.11
28	.02 " ROUND "G"				HAND		"	"	.13
29									
30	SETTING TOOLS								.86
31	SET CRANE TO WORK								.58
32	REMOVE LARGE FACING HEAD								.07
33	" 6" BAR, PUT IN END FOR END								.10
34	" 2-6 FOOT CLAMPS AND BOLTS								.10
35	LOOSEN 4-TIE-" OF REVOLVING PLATEN								.05
36	START AND TURN PLATEN 180°								.10
37	PUT LARGE FACING HEAD ON BAR								.13
38	SQUARE UP WORK BY SPINDLE								.05
39	TIGHTEN CIRCULAR PLATEN CLAMPS								.10
40	SET AND TIGHTEN 2-6 FT BOLTS & CLAMPS								.10
41	REPEAT OPERATIONS FROM 14 TO 30 (INCLUSIVE)								17 28
42	GET CRANE TO MACHINE								.25

DRAWING NO	WEIGHT	O D	FACE	BORE	KIND OF MATERIAL	CLASS	MACH NO	LOCATION	INITS	CARD NO
7-14-29 AL					C.S.		2BF	DN3	2/6	

43	REMOVE LARGE FACING HEAD								.07	
44	" 6" BAR								.10	
45	CHANGE 2 CLAMPS								.20	
46	LOOSE 4-TIE " OF REVOLVING PLATEN								.10	
47	START AND TURN TABLE								10	
48	PUT JIG INTO WORK								1 00	
49	PUT 5" BAR IN								10	
50	SQUARE WORK BAR SPINDLE								.10	
51	TIGHTEN 4 TIE-CLAMPS OF REVOLVING PLATEN								10	
52										
53	0.1 ROUGH BORE "A" 13½"		1		0.0125	3A	13.75	5A	1.43	
54	0.1 " " "A" 13½"		1		.002	4A	18.5	6A	.66	
55	0.1 " OUT "F" 7"		1		0.0125	3A	10.0	4A	1 00	
56	0.1 FINISH BORE "A" 13½"		1		0.02	4A	13.75	5A	90	
57	0.05 ROUGH OUT "B" IN 4½"				0.0125	3A	7.3	3A	90	
58	0.05 " " "B" OUT 4½"				"	"	"	"	.90	
59	0.1 " BORE "C" 49"				"	"	10.0	4A	7 15	
60	" " BOTTOM 1"				0.0062	2A	"	"	22	
61	0.1 " " "C" 49"				.007	4A	19.75	5A	2.81	
62	" " BOTTOM 1"				0.0062	2A	"	"	17	
63	0.1 FINISH " "C" 49"				0.02	4A	"	"	2.91	
64	" " BOTTOM EBD RING				0.0062	2A	"	"	17	
65	0.1 SQUARE BOTTOM				HAND		39.2	1A	35	
66	[illegible] REAM				.002	4A	7.3	3A	6.05	
67	0.1 BORE FOR THD. 3"				"	"	13.75	5A	.23	
68	0.1 CHAMFER " "				HAND		"	"	08	
69	0.2 GROOVE " "				"		7.3	3A	.25	
70	PUT THREAD GAUGE ON BAR								.15	
71	SET CHASER ATTACHMENT								25	
72	0.1 THREAD 6" RUN		18		0.125		5.4	2A	2.68	
73	TRY THREAD GAUGE								.60	
74	REMOVE CHASER ATTACHMENT								10	
75	" THREAD GAUGE FROM BAR								.15	
76	SETTING TOOLS								2.30	
77										
78	GET CRANE								.25	
79	REMOVE BAR & PUT IN OTHER CYLINDER								.20	
80	PUT BAR ON SPINDLE								.10	
81										
82	REPEAT OPERATIONS 53 TO 76								32.31	
83										
84	GET CRANE								.25	
85	REMOVE BAR FROM CYLINDER								10	
86	INSPECT								1.00	
87	GET CRANE								.25	
88	REMOVE JIG								60	
89	" CLAMPS								.30	
90	" WORK								.25	
91										
92									17.47	HR
93										
94										
95										
96										
97										
98										
99										
100										
101										
102										
103										
104										
105										

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD		MONTH 11	DAY 11	1917	SIGNED D.W.—

FIG. 63.—INSTRUCTION CARD FOR MACHINING A CRADLE FOR A 12-IN. MOTOR



INSTRUCTION CARD — DEPARTMENT: DF — ORDER NUMBER: 6416-122

NAME OR SYMBOL OF PIECE: SCALE AZIMUTH.

OPERATION: MAKE & CLOSE MOLD.

KIND OF MATERIAL: BZ. — PATTERN NUMBER: 81-48 — METHOD OF MOULDING: GRH — RIGGING: DC — KIND OF PATT: R — KIND OF FLASK: W

SIZE OF FLASK: C 54"x44"x8"; B 54"x44"x9" — DRAWING NO: 7-16-13 — INSTR CARD NO: 470. — NO OF PIECES PER FLASK: 1

TIME WORK SHOULD TAKE, PER PIECE: 3HR. 10 MIN — TIME BASIS HRS: 3HR. 15 MIN.

TIME TAKEN FROM: PATT. NO. J-6-A-INST. CARD NO. 234; PATT. NO. F-W-82-INST CARD NO. 162

DETAILED INSTRUCTIONS

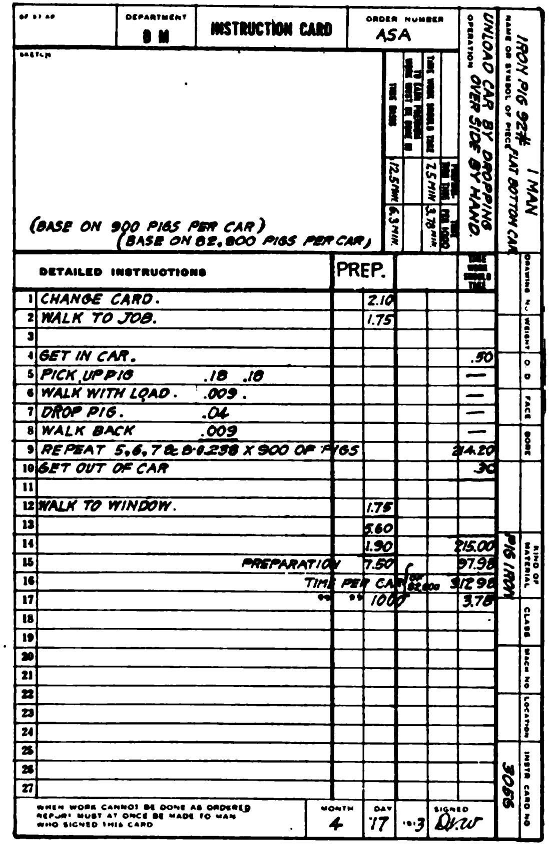
1. PUT PARTING BOARD DOWN & LEVEL. PUT DRAG ON PARTING BOARD.
2. PUT PATTERN ON BOARD. RIDDLE SAND ON PATTERN.
3. FILLING TIME. RAMMING TIME.
4. STRIKE OFF. LEVEL OFF WITH LOOSE SAND.
5. NAIL BOTTOM BOARD. GET 4 CLAMPS.
6. ROLL OVER. MAKE JOINT.
7. PARTING SAND. GET CLAY WASH & GAGGERS.
8. RIDDLE SAND. BRUSH SAND OFF EDGE OF FLASK.
9. CLAY WASH COPE. PUT COPE ON DRAG.
10. SET RISERS & SPRUE. SET GAGGERS.
11. RIDDLE SAND. TUCK & RAM AROUND BARS.
12. FILLING TIME. RAMMING TIME.
13. STRIKE OFF. DRAW RISERS AND SPRUE.
14. FINISH RISERS. LIFT COPE.
15. BRUSH OFF COPE AND DRAG. PATCH COPE.
16. BLACK COPE. SWAB DRAG & DRAW PATTERN.
17. PATCH. CUT GATE.
18. BLACK DRAG. BLOW OFF.
19. CLOSE MOLD. CLAMP & WEDGE.
20.
21. ALLOWANCE OF 50%
22.

RAM UP & ROLL OVER DRAG; RAM UP COPE 38.98; FINISH DRAG & COPE 36.80

MONTH 2 — DAY 9 — 1912 — SIGNED C.M.W.

WHEN WORK CANNOT BE DONE AS ORDERED, REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD.

FIG. 64.—INSTRUCTION CARD FOR MAKING AND CLOSING A MOLD



INSTRUCTION CARD — DEPARTMENT: B M — ORDER NUMBER: ASA

NAME OR SYMBOL OF PIECE: IRON PIG 92# FLAT BOTTOM CAR — 1 MAN

OPERATION: UNLOAD CAR BY DROPPING OVER SIDE BY HAND.

KIND OF MATERIAL: PIG IRON — INSTR CARD NO: 3056

	PREPARATION TIME	TIME PER 1000
TIME WORK SHOULD TAKE	7.5 MIN	3.78 MIN.
TO EARN PREMIUM WORK MUST BE DONE IN		
TIME BASIS	12.5 MIN.	6.3 MIN.

(BASE ON 900 PIGS PER CAR)
(BASE ON 82,800 PIGS PER CAR)

	DETAILED INSTRUCTIONS		PREP.		TIME WORK SHOULD TAKE
1	CHANGE CARD.		2.10		
2	WALK TO JOB.		1.75		
3					
4	GET IN CAR.				.50
5	PICK UP PIG	.18 .18			—
6	WALK WITH LOAD.	.009 .			—
7	DROP PIG.	.04			—
8	WALK BACK	.009			—
9	REPEAT 5,6,7 & 8 0.238 x 900 OF PIGS				214.20
10	GET OUT OF CAR				.30
11					
12	WALK TO WINDOW.		1.75		
13			5.60		
14			1.90		215.00
15		PREPARATION	7.50		97.98
16		TIME PER CAR		100/82,800	312.98
17			1000		3.78

MONTH 4 — DAY 17 — 1913 — SIGNED D.W.

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD

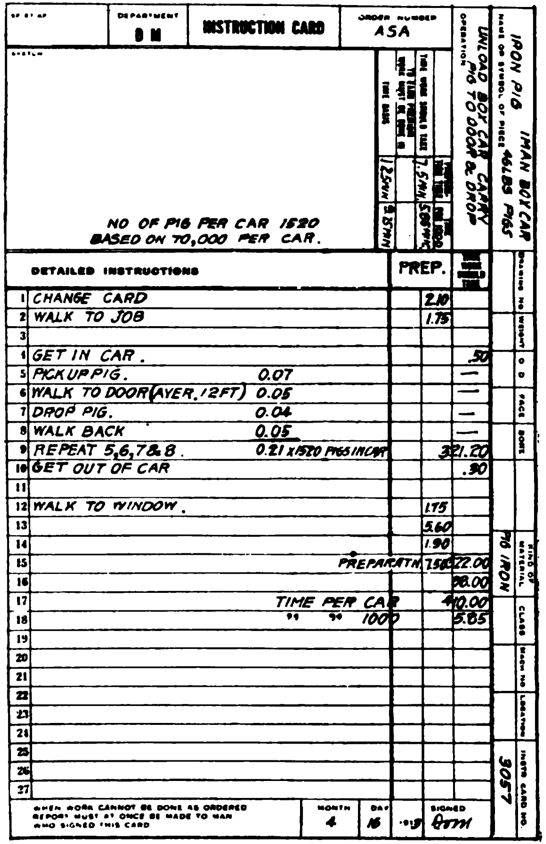
FIG. 65.—INSTRUCTION CARD FOR UNLOADING FLAT-BOTTOM FREIGHT CARS

In Fig. 64 is illustrated another instruction card from the Watertown Arsenal when the Halsey Premium Plan of payment was in force. It was made up to govern the making and closing of a mold in the foundry, a task for which series of comprehensive time studies in the form of properly classified data of unit times for fundamental operations were not available. The instruction cards list a sequence of elementary operations with the unit times for each, as ascertained from time studies taken on the various elements, and a generous allowance is added to the sum of the unit times to establish the task time. The unit times embraced by brackets indicate sequences of elementary operations it was believed further study of molding operations would show could be combined into fundamental operations for which definite unit times could be established.

The instruction cards presented as Figs. 65, 66 and 67, also from the Watertown Arsenal, are for quite different classes of work, entailing almost entirely hand work. Fig. 65 depicts an instruction card for unloading 92-lb. iron pigs from a flat-bottom freight car by simply dropping the pigs over the side of the car by hand; Fig. 66, one for a man to unload 46-lb. iron pigs from a box car by carrying them to one of the side doors and dropping them over the side; while Fig. 67 illustrates a card giving full instructions and unit times for a man to personally load a cart with 46-lb. half pigs from a pile and cart them to a cupola, weighing his load on platform scales on the way.

The instruction cards list the elementary operations entailed for the various jobs with unit times determined from time studies conducted on the various elements. Preparation time was separated from the time allowed for actual productive work and in setting rates a uniform allowance of 33⅓ per cent. was added to the preparatory time as determined from the time studies and a suitable allowance to the productive time. In the latter instance the percentage of allowance differed for the three jobs. An allowance of 45 per cent. was added in the case of unloading flat-bottom freight cars, but of only 27¼ per cent. in the case of work in the box car, as the pigs weighed but half as much as those handled in unloading the open car. The allowance by which the productive time was increased in the carting operation was 25 per cent., the pigs being but of half full weight and the work less fatiguing.

The rates as set by time studies were in force for three or four years and it is interesting to note that workmen who worked on these rates under the Halsey Premium Plan of recom-



INSTRUCTION CARD

Department: DM — Order Number: ASA — Instr. Card No.: 3057

Name or Symbol of Piece: IRON PIG 1 MAN BOX CAR 46 LBS PIGS

Operation: UNLOAD BOX CAR CARRY PIG TO DOOR & DROP

Kind of Material: PIG IRON

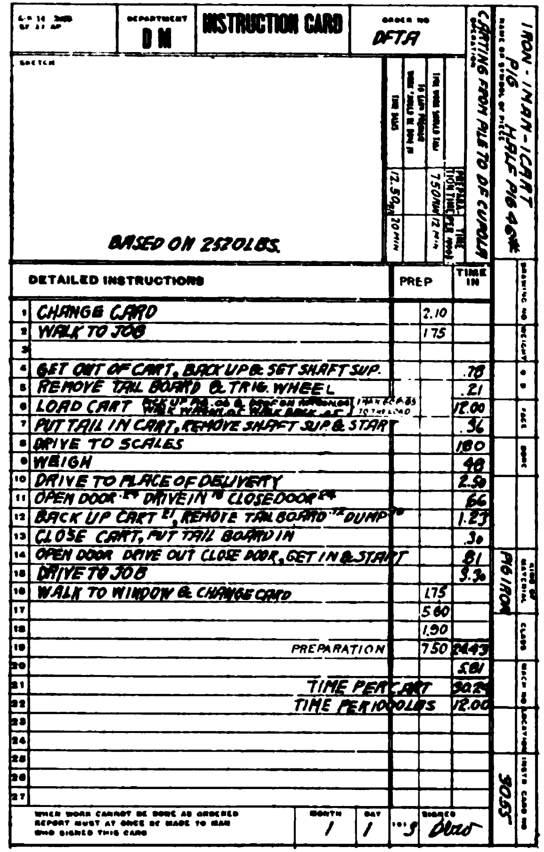
	Preparation Time	Time per 1000
Time work should take	7.5 MIN	5.85 MIN
Time basis	12.5 MIN	9.15 MIN

NO OF PIG PER CAR 1520
BASED ON 70,000 PER CAR.

	Detailed Instructions	Prep.	Time
1	CHANGE CARD	2.10	
2	WALK TO JOB	1.75	
3			
4	GET IN CAR.		.50
5	PICK UP PIG. 0.07		—
6	WALK TO DOOR (AYER. 12 FT) 0.05		—
7	DROP PIG. 0.04		—
8	WALK BACK 0.05		—
9	REPEAT 5, 6, 7 & 8. 0.21 x 1520 PIGS IN CAR		321.20
10	GET OUT OF CAR		.90
11			
12	WALK TO WINDOW.	1.75	
13		5.60	
14		1.90	
15	PREPARATN	7.50	322.00
16			98.00
17	TIME PER CAR		410.00
18	" " 1000		5.85
19			
20			
21			
22			
23			
24			
25			
26			
27			

When work cannot be done as ordered report must at once be made to man who signed this card — Month 4 — Day 16 — 1915 — Signed

FIG. 66.—INSTRUCTION CARD FOR UNLOADING BOX CARS



INSTRUCTION CARD

Department: DM — Order No.: DFTA — Instr. Card No.: 3055

Name or Symbol of Piece: IRON - 1 MAN - 1 CART PIG HALF PIG 46#

Operation: CARTING FROM PILE TO DF CUPOLA

Kind of Material: PIG IRON

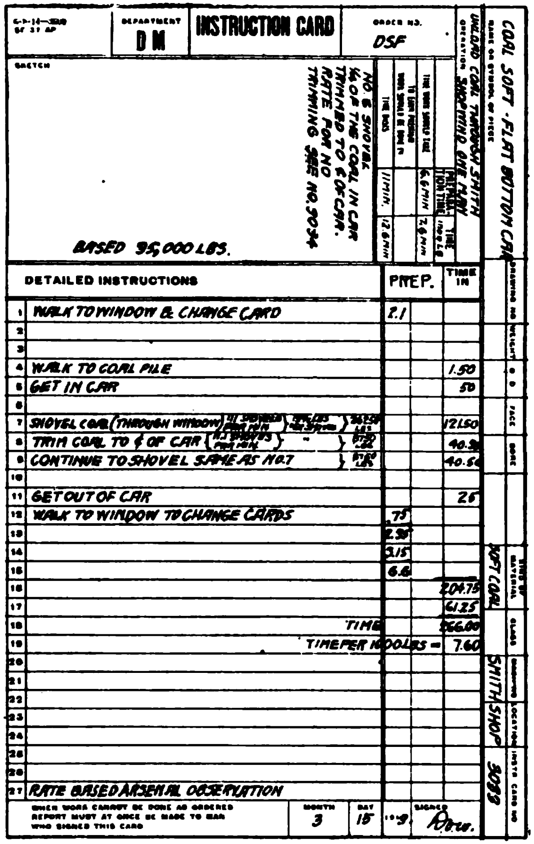
	Preparation Time	Time per 1000
Time work should take	750 MIN	12 MIN
Time basis	12.50 MIN	20 MIN

BASED ON 2520 LBS.

	Detailed Instructions	Prep	Time In
1	CHANGE CARD	2.10	
2	WALK TO JOB	1.75	
3			
4	GET OUT OF CART, BACK UP & SET SHAFT SUP.		.78
5	REMOVE TAIL BOARD & TRIG. WHEEL		.21
6	LOAD CART		12.00
7	PUT TAIL IN CART, REMOVE SHAFT SUP. & START		.36
8	DRIVE TO SCALES		1.80
9	WEIGH		.48
10	DRIVE TO PLACE OF DELIVERY		2.50
11	OPEN DOOR, DRIVE IN, CLOSE DOOR		.66
12	BACK UP CART, REMOVE TAIL BOARD, DUMP		1.23
13	CLOSE CART, PUT TAIL BOARD IN		.30
14	OPEN DOOR DRIVE OUT CLOSE DOOR, GET IN & START		.81
15	DRIVE TO JOB		3.36
16	WALK TO WINDOW & CHANGE CARD	1.75	
17		5.60	
18		1.90	
19	PREPARATION	7.50	24.43
20			5.81
21	TIME PER CART		30.24
22	TIME PER 1000 LBS		12.00
23			
24			
25			
26			
27			

When work cannot be done as ordered report must at once be made to man who signed this card — Month 1 — Day 1 — 1915 — Signed

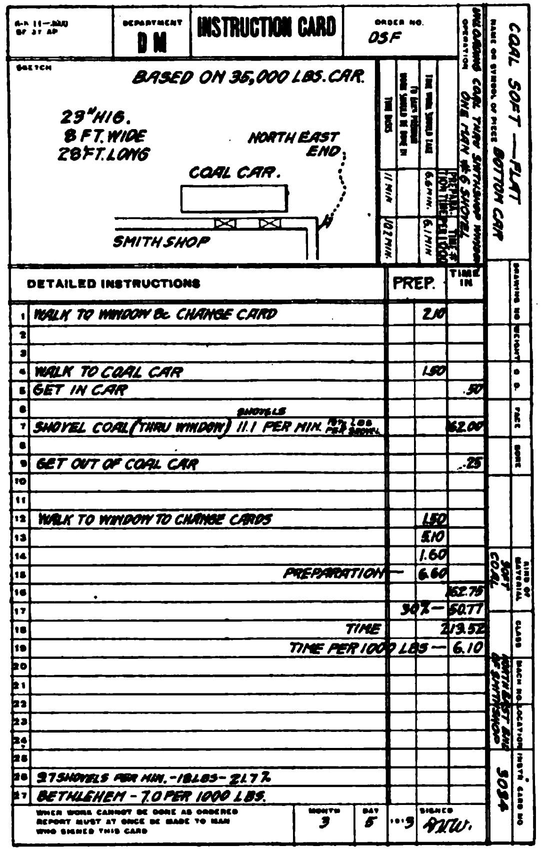
FIG. 67.—INSTRUCTION CARD FOR CARTING IRON PIGS


INSTRUCTION CARD
Department: D M
Order No.: DSF
Name or symbol of piece: COAL SOFT - FLAT BOTTOM CAR
Operation: UNLOAD COAL THROUGH SMITH SHOP WIND ONE MAN
Time work should take: Preparation time 6.6 MIN; Time per 1000 LB 7.6 MIN
Time basis: 11 MIN, 12.6 MIN
Sketch: NO. 6 SHOVEL. 1/4 OF THE COAL IN CAR TRIMMED TO 1/4 OF CAR. RATE FOR NO TRIMMING SEE NO. 3034. BASED 35,000 LBS.
Kind of material: SOFT COAL
Location: SMITH SHOP
Instr. card no.: 3033

	Detailed Instructions	Prep.	Time in
1	WALK TO WINDOW & CHANGE CARD	2.1	
4	WALK TO COAL PILE		1.50
5	GET IN CAR		50
7	SHOVEL COAL (THROUGH WINDOW)		121.50
8	TRIM COAL TO 1/4 OF CAR		40.5
9	CONTINUE TO SHOVEL SAME AS NO. 7		40.5
11	GET OUT OF CAR		25
12	WALK TO WINDOW TO CHANGE CARDS	.75	
13		2.25	
14		3.15	
15		6.6	
16			204.75
17			61.25
18	TIME		266.00
19	TIME PER 1000 LBS =		7.60
27	RATE BASED ARSENAL OBSERVATION		

Month 3, Day 15, 19–, Signed

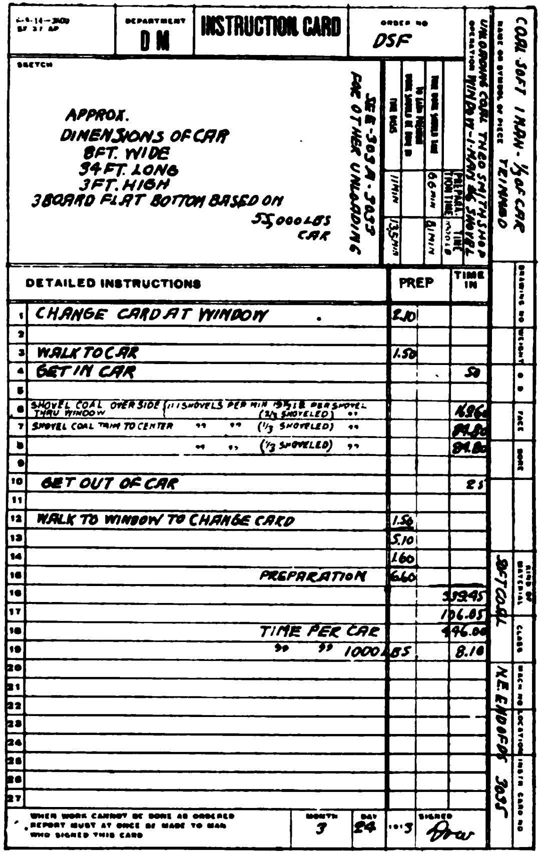
FIG. 68.—INSTRUCTION CARD FOR UNLOADING SOFT COAL FROM FLAT-BOTTOM FREIGHT CARS


INSTRUCTION CARD
Department: D M
Order No.: OSF
Name or symbol of piece: COAL SOFT —FLAT BOTTOM CAR
Operation: UNLOADING COAL THRU SMITH SHOP WINDOW ONE MAN #6 SHOVEL
Time work should take: Preparation time 6.6 MIN.; Time per 1000 6.1 MIN
Time basis: 11 MIN, 10.2 MIN.
Sketch: BASED ON 35,000 LBS. CAR. 23" HIG. 8 FT. WIDE 28 FT. LONG. NORTH EAST END. COAL CAR. SMITH SHOP
Kind of material: SOFT COAL
Location: NORTH EAST END OF SMITH SHOP
Instr. card no.: 3034

	Detailed Instructions	Prep.	Time in
1	WALK TO WINDOW & CHANGE CARD	2.10	
4	WALK TO COAL CAR	1.50	
5	GET IN CAR		.50
7	SHOVEL COAL (THRU WINDOW) 11.1 SHOVELS PER MIN.		162.00
9	GET OUT OF COAL CAR		.25
12	WALK TO WINDOW TO CHANGE CARDS	1.50	
13		5.10	
14		1.60	
15	PREPARATION—	6.60	
16			162.75
17		30%—	50.77
18	TIME		213.52
19	TIME PER 1000 LBS—		6.10
26	27 SHOVELS PER MIN. -18 LBS- 21.7%		
27	BETHLEHEM - 7.0 PER 1000 LBS.		

Month 3, Day 5, 19–, Signed

FIG. 69.—INSTRUCTION CARD FOR UNLOADING COAL CARS THROUGH A SMITH SHOP WINDOW



INSTRUCTION CARD

Department: D M. Order No.: DSF

Name or symbol of piece: COAL SOFT 1 MAN - ⅓ OF CAR TRIMMED

Operation: UNLOADING COAL THRO SMITHSHOP WINDOW - 1 MAN #6 SHOVEL

	Preparation time	Time (each)
Time work should take	66 MIN	81 MIN
Time basis	11 MIN	13.5 MIN

Sketch: APPROX. DIMENSIONS OF CAR 8 FT. WIDE 34 FT. LONG 3 FT. HIGH 3 BOARD FLAT BOTTOM BASED ON 55000 LBS CAR

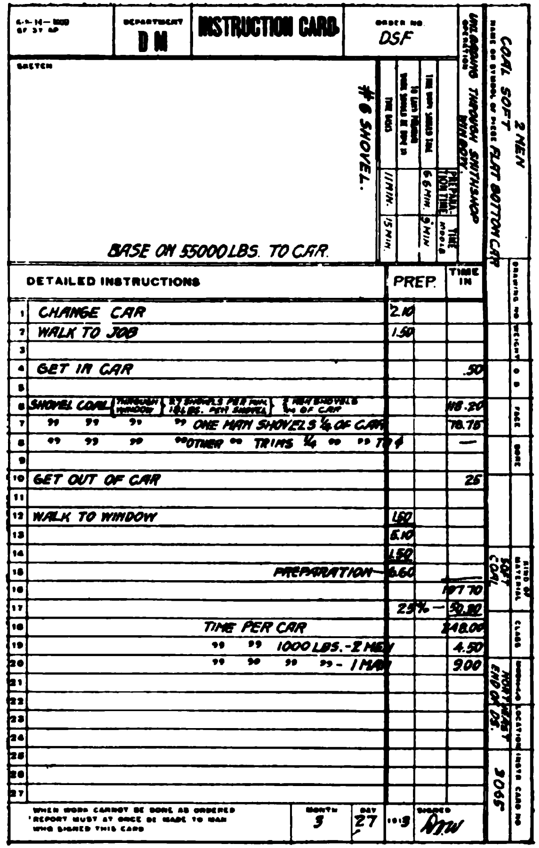
SEE 303A - 3033 FOR OTHER UNLOADING

Kind of material: SOFT COAL. Location: N.E. END OF DS. Instr. card no.: 3035

	Detailed instructions	Prep	Time in
1	CHANGE CARD AT WINDOW	2.10	
2			
3	WALK TO CAR	1.50	
4	GET IN CAR		.50
5			
6	SHOVEL COAL OVER SIDE THRU WINDOW (11 SHOVELS PER MIN 15 LB PER SHOVEL) (⅓ SHOVELED)		4.86
7	SHOVEL COAL TRIM TO CENTER " " (⅓ SHOVELED) "		84.80
8	" " (⅓ SHOVELED) "		84.80
9			
10	GET OUT OF CAR		25
11			
12	WALK TO WINDOW TO CHANGE CARD	1.50	
13		5.10	
14		1.60	
15	PREPARATION	6.60	
16			339.45
17			106.85
18	TIME PER CAR		446.00
19	" " 1000 LBS		8.10

Month 3, Day 24, 1913. Signed [illegible]

FIG. 70.—INSTRUCTION CARD FOR ONE MAN TO UNLOAD A SOFT-COAL CAR UNDER SPECIAL CONDITIONS



INSTRUCTION CARD

Department: D M. Order No.: DSF

Name or symbol of piece: 2 MEN COAL SOFT FLAT BOTTOM CAR

Operation: UNLOADING THROUGH SMITHSHOP WINDOW.

	Preparation time	Time (each)
Time work should take	66 MIN.	9 MIN
Time basis	11 MIN.	15 MIN.

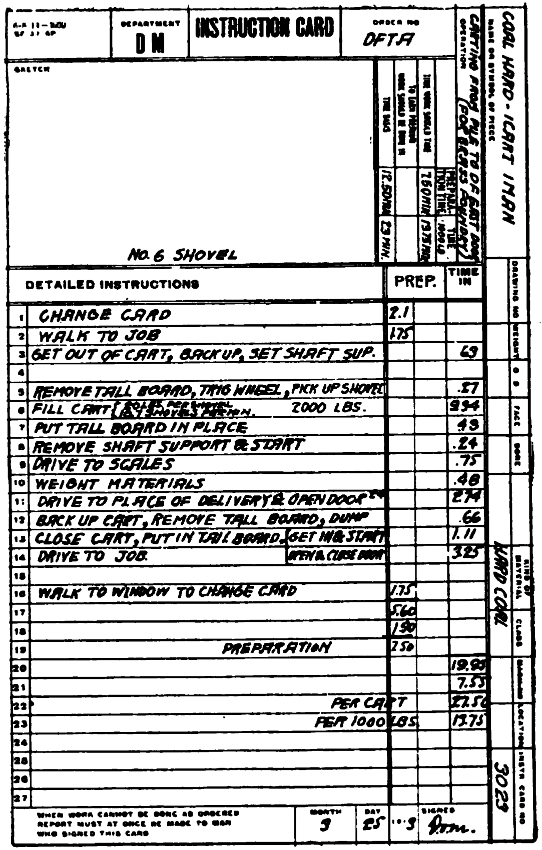
Sketch: #6 SHOVEL. BASE ON 55000 LBS. TO CAR.

Kind of material: SOFT COAL. Location: NORTHWEST END OF DS. Instr. card no.: 3065

	Detailed instructions	Prep	Time in
1	CHANGE CAR	2.10	
2	WALK TO JOB	1.50	
3			
4	GET IN CAR		.50
5			
6	SHOVEL COAL THROUGH WINDOW (37 SHOVELS PER MIN. 15 LBS. PER SHOVEL) (2 MEN SHOVELS ½ OF CAR)		118.20
7	" " " " ONE MAN SHOVELS ¼ OF CAR		78.75
8	" " " " OTHER " TRIMS ¼ " " "		—
9			
10	GET OUT OF CAR		25
11			
12	WALK TO WINDOW	1.60	
13		6.10	
14		1.50	
15	PREPARATION	6.60	
16			197.70
17		25%	50.30
18	TIME PER CAR		248.00
19	" " 1000 LBS. - 2 MEN		4.50
20	" " " " - 1 MAN		9.00

Month 3, Day 27, 1913. Signed [illegible]

FIG. 71.—INSTRUCTION CARD FOR TWO MEN TO UNLOAD A SOFT-COAL CAR UNDER SPECIAL CONDITIONS



INSTRUCTION CARD — DEPARTMENT: D M — ORDER NO.: OFTA

NAME OR SYMBOL OF PIECE: COAL HARD - 1 CART 1 MAN

OPERATION: CARTING FROM PILE TO OF EAST DOOR (FOR BRASS FOUNDRY)

	PREPARATION TIME	TIME 1000 LB.
TIME WORK SHOULD TAKE	7.60 MIN.	13.75 MIN.
TO EARN PREMIUM WORK SHOULD BE DONE IN		
TIME BASIS	12.50 MIN.	23 MIN.

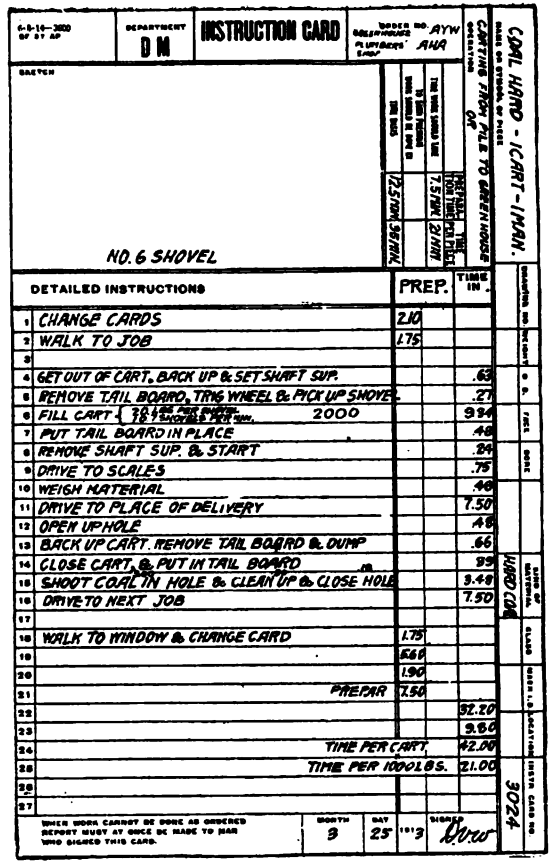
SKETCH: NO. 6 SHOVEL

	DETAILED INSTRUCTIONS	PREP.	TIME IN.
1	CHANGE CARD	2.1	
2	WALK TO JOB	1.75	
3	GET OUT OF CART, BACK UP, SET SHAFT SUP.		.63
4			
5	REMOVE TAIL BOARD, TRIG WHEEL, PICK UP SHOVEL		.57
6	FILL CART { SCALES PER SHOVEL / SHOVELS PER MIN. } 2000 LBS.		9.94
7	PUT TAIL BOARD IN PLACE		.43
8	REMOVE SHAFT SUPPORT & START		.24
9	DRIVE TO SCALES		.75
10	WEIGHT MATERIALS		.48
11	DRIVE TO PLACE OF DELIVERY & OPEN DOOR		2.74
12	BACK UP CART, REMOVE TAIL BOARD, DUMP		.66
13	CLOSE CART, PUT IN TAIL BOARD, GET IN & START		1.11
14	DRIVE TO JOB, OPEN & CLOSE DOOR		3.25
15			
16	WALK TO WINDOW TO CHANGE CARD	1.75	
17		5.60	
18		1.90	
19	PREPARATION	7.50	
20			19.95
21			7.55
22	PER CART		27.50
23	PER 1000 LBS.		13.75
24			
25			
26			
27			

KIND OF MATERIAL: HARD COAL — INSTR. CARD NO.: 3023

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD. MONTH 3 DAY 25 1913 SIGNED [illegible]

FIG. 72.—INSTRUCTION CARD FOR CARTING HARD COAL FROM PILE TO FOUNDRY



INSTRUCTION CARD — DEPARTMENT: D M — ORDER NO.: AYW — GREENHOUSE PLUMBERS' SHOP: AHA

NAME OR SYMBOL OF PIECE: COAL HARD - 1 CART - 1 MAN.

OPERATION: CARTING FROM PILE TO GREENHOUSE OR

	PREPARATION TIME	TIME PER PIECE
TIME WORK SHOULD TAKE	7.5 MIN.	21 MIN.
TO EARN PREMIUM WORK SHOULD BE DONE IN		
TIME BASIS	12.5 MIN.	35 MIN.

SKETCH: NO. 6 SHOVEL

	DETAILED INSTRUCTIONS	PREP.	TIME IN.
1	CHANGE CARDS	2.10	
2	WALK TO JOB	1.75	
3			
4	GET OUT OF CART. BACK UP & SET SHAFT SUP.		.63
5	REMOVE TAIL BOARD, TRIG WHEEL & PICK UP SHOVEL		.27
6	FILL CART { LBS. PER SHOVEL / SHOVELS PER MIN. } 2000		9.94
7	PUT TAIL BOARD IN PLACE		.48
8	REMOVE SHAFT SUP. & START		.24
9	DRIVE TO SCALES		.75
10	WEIGH MATERIAL		.46
11	DRIVE TO PLACE OF DELIVERY		7.50
12	OPEN UP HOLE		.48
13	BACK UP CART. REMOVE TAIL BOARD & DUMP		.66
14	CLOSE CART, & PUT IN TAIL BOARD		.99
15	SHOOT COAL IN HOLE & CLEAN UP & CLOSE HOLE		3.48
16	DRIVE TO NEXT JOB		7.50
17			
18	WALK TO WINDOW & CHANGE CARD	1.75	
19		5.60	
20		1.90	
21	PREPAR	7.50	
22			32.20
23			9.80
24	TIME PER CART		42.00
25	TIME PER 1000 LBS.		21.00
26			
27			

KIND OF MATERIAL: HARD COAL — INSTR. CARD NO.: 3024

WHEN WORK CANNOT BE DONE AS ORDERED REPORT MUST AT ONCE BE MADE TO MAN WHO SIGNED THIS CARD. MONTH 3 DAY 25 1913 SIGNED [illegible]

FIG. 73.—INSTRUCTION CARD FOR CARTING HARD COAL FROM PILE TO GREENHOUSE

INSTRUCTION CARD — Department: D M — Order No.: DFTA

Name or symbol of piece: COKE 1 MAN 1 CART

Operation: CARTING FROM SHED TO WEST DOOR OF DP. NOTE SIDE BOARD ON CART.

	Prepara-tion time	Time per cart
Time work should take	7.50 MIN.	78 MIN.
To earn premium work should be done in		
Time given	12.60 MIN.	47 MIN.

(CART FULL FULL)

NO. 6 SHOVEL - OR FORK

	Detailed Instructions	Prep.		Time In
1	CHANGE CARD	2.10		
2	WALK TO JOB	1.75		
3				
4	GET OUT OF CART, BACK UP & SET SHAFT SUP.			.60
5	REMOVE TAIL BOARD, TRIG WHEEL & PICK UP SHOVEL			.27
6	FILL CART (ABOUT 700 LBS)			11.40
7	PUT TAIL BOARD IN PLACE, PILE LARGE PIECE ON BACK			1.90
8	REMOVE SHAFT SUP. & START			.24
9	DRIVE TO WEST DOOR OF DP			2.50
10	OPEN DOOR, BACK IN CART, REMOVE TAIL BOARD			.72
11	DUMP, CLOSE CART, PUT IN TAIL BOARD			.78
12	OPEN DOOR DRIVE OUT & CLOSE DOOR			.66
13	DRIVE TO JOB			2.50
14				
15	WALK TO WINDOW TO CHANGE CARD	1.75		
16		5.60		
17		1.80		
18	PREPARATION	7.50		
19				21.60
20			90%	6.40
21				28.00
22				
23				
24				
25				
26				
27				

Kind of material: COKE — Instr. card No.: 3027

When work cannot be done as ordered report must at once be made to man who signed this card. Month 9 Day 25 1919 Signed DMW.

FIG. 74.—INSTRUCTION CARD FOR CARTING COKE

INSTRUCTION CARD — Department: D M — Order No.: AHA

Name or symbol of piece: ASHES 3 CART & 4 MEN

Operation: CARTING FROM BOILER HOUSE DUMP TO DUMP N.E. OF HOSPITAL

	Prepara-tion time	Time per cart
Time work should take	6.6 MIN.	49.2 MIN.
To earn premium work should be done in		
Time given	11 MIN.	82 MIN.

3 CART & 4 MEN
2 MEN CONTINUALLY SHOVELING INTO CARTS AND AS SOON AS ONE IS FILLED, ONE STARTS TO DUMP WITH IT.

NO. 6 SHOVEL

	Detailed Instructions	Prep.		Time In
1	CHANGE CARD	2.10		
2	WALK TO JOB	1.50		
3				
4	BACK UP CART, SET SHAFT SUPPORT, & REMOVE TAIL BOARD			.69
5	FILL CART			6.25
6	PUT TAIL BOARD IN PLACE			.48
7	REMOVE SHAFT SUPPORT & DRIVE OUT OF WAY			.24
8				
9	START FOR DUMP		.24	
10	DRIVE TO DUMP 2400 FT		9.50	
11	BACK UP CART, REMOVE TAIL BOARD & DUMP		.66	
12	CLOSE CART, PUT TAIL BOARD IN, GET IN & START		.45	
13	DRIVE BACK TO BOILER HOUSE		9.00	
14				
15	WALK TO WINDOW TO CHANGE CARDS	1.60		
16		5.20		10.85
17	PREPARATION	6.60		27.46
18				9.65
19	TIME PER TRIP ONE CART			37.00
20	CART OR TRIPS PER DAY = 13 X 3 CARTS =			39
21				129
22				492
23				
24				
25				
26				
27				

Kind of material: ASHES — Location: BOILER HOUSE — Instr. card No.: 3020

When work cannot be done as ordered report must at once be made to man who signed this card. Month 9 Day 8 1919 Signed DMW.

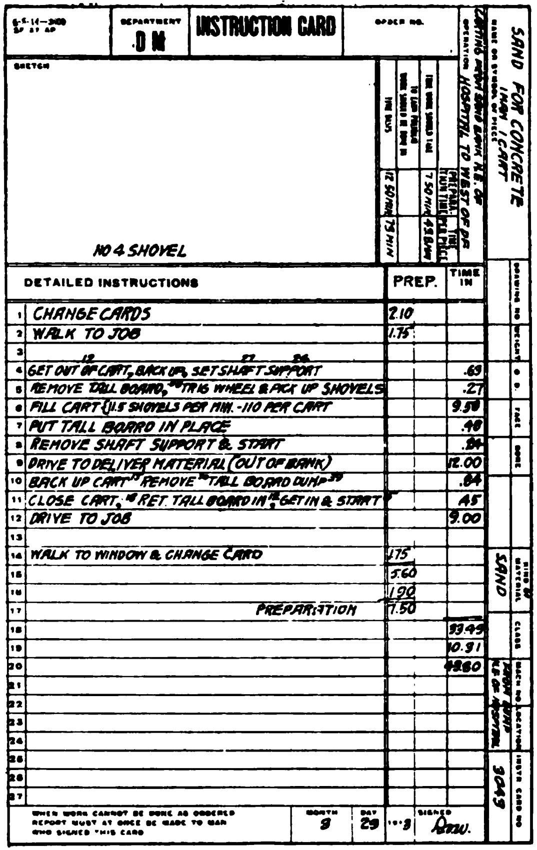
FIG. 75.—INSTRUCTION CARD FOR CARTING ASHES

pense made a premium, or bonus, of more than 33⅓ per cent. and did anywhere from 1½ to 2½ times as much work as they did when on day work. These gratifying results, which were noted in the reports of the Chief of Ordnance for the year 1912–1913, however, did not prevent the United States Congress from abolishing all rate setting from time-study work as well as the Halsey Premium Plan of recompensing the workers from all Government establishments.

Figs. 68 to 81, inclusive, illustrate several other instruction cards from the Watertown Arsenal setting rates for quite a variety of handling tasks from time studies taken on the various elementary operations involved. Preparation time was in each case separated from what may be termed the productive times and suitable allowances added to each group. The respective instruction cards clearly indicate the character of the work involved and the procedure established in each instance. The cards are presented more as indications that it is practical to time study and rate almost any kind of work involving a definite task than as examples of any particular type of instruction cards.

The cuts shown in Figs. 82 and 83 and those in Figs. 84 and 85 are front and back views of job cards used at the Watertown Arsenal in connection with work rated by time studies and are forms used in the Taylor System, introduced by Carl G. Barth. On the back of the card, shown in Fig. 85, there is a space for concise instructions and also a space in which to insert the task time, or the time the work should take, and the time basis, from which the premium earnings are figured. This form for the back of the job card is particularly suitable for work of a jobbing nature and where it is necessary for the workman to change his job several times during the day. In such cases it is advisable to show the rate for the job on the workman's job card. When the rates are standard or taken from rate tables, and few instructions will suffice or when an alteration can be made on an analogous instruction card to serve for a special job, the instruction space on the back of the card can be used for the purpose. There is also a space for the insertion of the standard instruction card number. The job card shown in Figs. 82 and 83 calls for instruction card No. 3056, illustrated in Fig. 65.

Figs 84 and 85 illustrate a job card, face and back, for turning and facing a line of standard bronze bushings. It is issued for the second operation on the work, as noted on the face of the job card, and is to be performed in an engine lathe, information which is also given on the face of the card by symbol. As the


SAND FOR CONCRETE, 1 MAN 1 CART (name or symbol of piece)

Operation: CARTING FROM SAND BANK N.E. OF HOSPITAL TO WEST OF PR

Department: D M — INSTRUCTION CARD — Order No.

	Preparation time	Time per piece
Time work should take	7 50 MIN	49.8 MIN
To earn premium work should be done in		
Time days	12 50 MIN	73 MIN

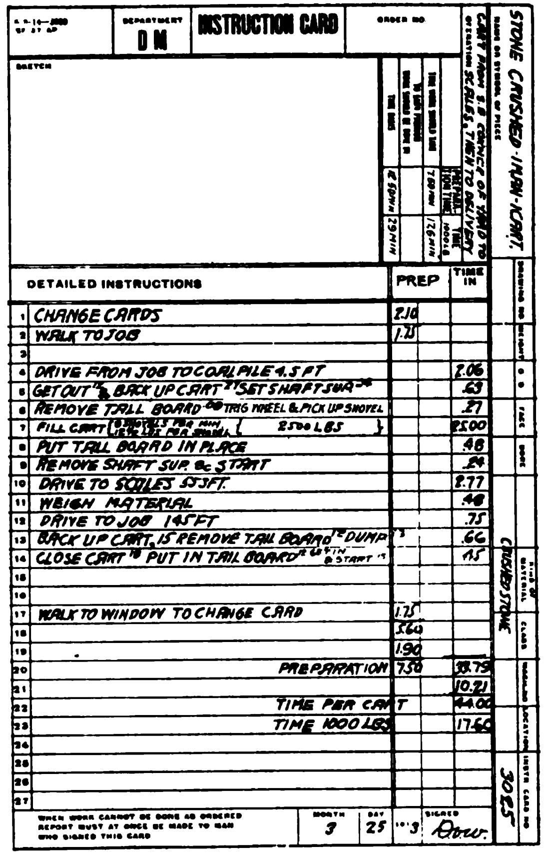
Sketch: NO 4 SHOVEL

	DETAILED INSTRUCTIONS	PREP.	TIME IN
1	CHANGE CARDS	2.10	
2	WALK TO JOB	1.75	
3			
4	GET OUT OF CART, BACK UP, SET SHAFT SUPPORT		.63
5	REMOVE TAIL BOARD, TRIG WHEEL & PICK UP SHOVELS		.27
6	FILL CART {11.5 SHOVELS PER MIN. -110 PER CART		9.50
7	PUT TAIL BOARD IN PLACE		.48
8	REMOVE SHAFT SUPPORT & START		.24
9	DRIVE TO DELIVER MATERIAL (OUT OF BANK)		12.00
10	BACK UP CART REMOVE TAIL BOARD DUMP		.84
11	CLOSE CART, RET. TAIL BOARD IN, GET IN & START		.45
12	DRIVE TO JOB		9.00
13			
14	WALK TO WINDOW & CHANGE CARD	1.75	
15		5.60	
16		1.90	
17	PREPARATION	7.50	
18			33.49
19			10.91
20			[illegible]
21–27			

Kind of material: SAND — Class — Mach. No. / Location: SAND BANK N.E. OF HOSPITAL — Instr. card No. 3049

When work cannot be done as ordered report must at once be made to man who signed this card. Month 3 Day 29 1913 Signed Dow.

FIG. 76.—INSTRUCTION CARD FOR CARTING SAND


STONE CRUSHED - 1 MAN - 1 CART (name or symbol of piece)

Operation: CART FROM S.E. CORNER OF YARD TO SCALES, THEN TO DELIVERY

Department: D M — INSTRUCTION CARD — Order No.

	Preparation time	Time 1000 LB
Time work should take	7.50 MIN	17.6 MIN
To earn premium work should be done in		
Time days	12 50 MIN	29 MIN

Sketch:

	DETAILED INSTRUCTIONS	PREP	TIME IN
1	CHANGE CARDS	2.10	
2	WALK TO JOB	1.75	
3			
4	DRIVE FROM JOB TO COAL PILE 4.5 FT		2.06
5	GET OUT, BACK UP CART, SET SHAFT SUP.		.63
6	REMOVE TAIL BOARD, TRIG WHEEL & PICK UP SHOVEL		.27
7	FILL CART {8 SHOVELS PER MIN. 18.4 LBS PER SHOVEL} {2500 LBS}		25.00
8	PUT TAIL BOARD IN PLACE		.48
9	REMOVE SHAFT SUP. & START		.24
10	DRIVE TO SCALES 553 FT.		2.77
11	WEIGH MATERIAL		.48
12	DRIVE TO JOB 145 FT		.75
13	BACK UP CART, REMOVE TAIL BOARD, DUMP		.66
14	CLOSE CART, PUT IN TAIL BOARD, GET IN & START		.45
15			
16			
17	WALK TO WINDOW TO CHANGE CARD	1.75	
18		3.60	
19		1.90	
20	PREPARATION	7.50	38.79
21			10.21
22	TIME PER CART		44.00
23	TIME 1000 LBS		17.60
24–27			

Kind of material: CRUSHED STONE — Class — Mach. No. — Location — Instr. card No. 3025

When work cannot be done as ordered report must at once be made to man who signed this card. Month 3 Day 25 1913 Signed Dow.

FIG. 77.—INSTRUCTION CARD FOR CARTING CRUSHED STONE

Department: D M	INSTRUCTION CARD	Order No.:	Instr. Card No.: 3047
Name or symbol of piece: BRICK FIRE BOX CAR 3MEN		Kind of material: FIRE BRICK	Location: AT SAND SHEDS
Operation: REMOVE FROM CAR TO SHED			

	Preparation time	Time per 000
Time work should take	750 MIN	15 MIN
To earn premium work should be done in		
Time basis	1250 MIN	25 MIN

Sketch: + NOTE TIME PER 000 BRICK

BASED 6000 BRICK PER CAR

No.	Detailed Instructions		Prep.	Time in
1	CHANGE CARD		2.10	
2	WALK TO JOB		1.76	
3	60 180			
4	OPEN SHED & CAR DOORS			1.70
5	REMOVE BRICK FROM DOORWAY [illegible]			3.20
6	ONE MAN GET IN CAR	.06 PER BRICK		.36
7	REMOVE BRICK [illegible]			18.00
8	OPEN UP ROWS - 0.18 FOR EA. 40TH BRICK-(30 TIMES)		3.00	5.40
9	PUT PLANK FROM CAR TO SHED & PUT 2 WHEEL BARROW IN CAR			7.20
10	LOAD BARROW - ONE MAN 40 BRICKS .005 PER BRICK	.00		
11	WHEEL UP PLANK	.21		
12	UNLOAD & PILE 2MEN - .03 PER BRICK	1.20		
13	RETURN	.15		
14	WHEEL BARROW CONTAINS 40 BRICK 116 BARROW @ 1.96			56.60
15	REMOVE PLANK & REMOVE 2 BARROWS			4.00
16	CLOSE DOOR OF SHED			.50
17				
18	WALK TO WINDOW TO CHANGE CARD		1.75	
19			5.60	
20			1.90	
21	PREPARATION		7.50	226.96
22				72.04
23	FOR 3MEN TIME PER CAR			300.00
24	" " " " 1000			5.00
25	" 1MAN " " 1000			15.00
26				
27				

When work cannot be done as ordered report must at once be made to man who signed this card. Month 4 Day 2 1913 Signed Dow.

FIG. 78.—INSTRUCTION CARD FOR CARTING FIRE BRICK

Department: D M	INSTRUCTION CARD	Order No.: DSA	Instr. Card No.: 9049
Name or symbol of piece: WINDOWS INSIDE D SMITHSHOP		Mach. No.: DS	Location: INSIDE
Operation: CLEAN BY WASHING & DUSTING WITH WASTE & WIPING & POLISHING WITH WASTE			

	Preparation time	Time per pane
Time work should take	12 MIN.	1.40 MIN
To earn premium work should be done in		
Time basis	20 MIN	2.3 MIN

Sketch: PANES 10"x16"
45 PANES TO THE WINDOW

No.	Detailed Instructions	Prep.	Time in
1	CHANGE CARD	2.10	
2	WALK TO TOOL SHED & GET TOOLS	2.00	
3	WALK TO JOB	1.40	
4			
5	MOVE LADDER & PLACE IN ¢ OF WINDOW		.84
6	CLIMB LADDER WITH BRUSH		.21
7	DUST 5 PANES @ .09 PER PANE = 0.45 x 9		4.05
8	STEP DOWN ONE STEP .07 x 9		.63
9	DUST WINDOW SILL		1.20
10	MOVE TOOLS		.30
11	CLIMB LADDER WITH PAIL (5 PANES AT A TIME)		.21
12	WASH PANE WITH WET WASTE @ .36 PER PANE x 5 x 9		16.20
13	STEP DOWN ONE STEP .07 x 9		.63
14	CLIMB LADDER		.21
15	POLISH PANES (5 DOWN) @ .48 PER PANE x 5 x 9		21.60
16	STEP DOWN ONE STEP .07 x 9		.63
17	MOVE TOOLS		.30
18			
19	WALK TO TOOL SHED & PUT TOOL AWAY .25	1.65	
20	WALK TO WINDOW	1.75	
21		8.90	
22		3.10	48.01
23	PREPARATION	12.00	48.99
24	TIME PER WINDOW		63.00
25	" " PANE		1.40
26	TIME PER SQ. FT. 1.26		
27			

When work cannot be done as ordered report must at once be made to man who signed this card. Month 4 Day 10 1913 Signed Dow.

FIG. 79.—INSTRUCTION CARD FOR CLEANING INSIDE OF WINDOWS

INSTRUCTION CARD — Department: D M — Order No.: DSA

Name or symbol of piece: WINDOWS OUTSIDE SMITH SHOP

Operation: CLEAN WITH HOSE, & WASH WITH BRUSH ON STICK—PANE 10" x 16"

	Preparation Time	Time per Pane
Time work should take	12 MIN.	0.222 MIN.
To earn premium work should be done in		
Time basis	20 MIN.	37 MIN.

Sketch: 45 PANES TO WINDOW

No.	Detailed Instructions	Prep.	Time In
1	CHANGE CARD	2.10	
2	WALK TO TOOL SHED, GET HOSE	2.10	
3	WALK TO JOB	1.40	
4			
5	CONNECT HOSE FOR EA. 5th WINDOW		.81
6	WASH WINDOW WITH HOSE		.96
7	RINSE BRUSH		.12
8	WASH WINDOW WITH BRUSH-45 PANES @ .09		4.05
9	RINSE WINDOW WITH HOSE		1.50
10	MOVE TO NEXT WINDOW		.30
11			
12	WALK TO TOOL SHED	1.40	
13	PUT HOSE AWAY	.25	
14	WALK TO WINDOW TO CHANGE CARD	1.75	
15		8.90	
16		3.10	
17	PREPARATION	12.00	7.74
18		30%	2.26
19	TIME PER WINDOW		10.00
20	NOTE TWO MEN OPER. " " PANE		0.222
21	NO. 8 BECOMES 2.03		
22	THEN TIME PER PANE WILL		
23	BE 0.396 FOR ONE MAN TASK TIME		
24	0.56 " " " TIME BASIS TIME PER SQ. FT.	0.198	
25			
26			
27			

Machine: — Location: OS. OUTSIDE — Instr. Card No.: 3050

When work cannot be done as ordered report must at once be made to man who signed this card. Month 4 Day 10 19.. Signed D.W.

FIG. 80.—INSTRUCTION CARD FOR CLEANING OUTSIDE OF WINDOWS

INSTRUCTION CARD — Department: D M — Order No.: DMA

Name or symbol of piece: WINDOW—ALL WITHOUT USE OF LADDER—INSIDE ON ONE SIDE

Operation: CLEAN BY HAND (DM) APPROX. SIZE OF PANE 10" x 16"

	Preparation Time	Time per Pane
Time work should take	12 MIN.	1.1 MIN.
To earn premium work should be done in		
Time basis	20 MIN.	1.6 MIN.

Sketch: OR 160 SQ. IN. 30 PANE TO WINDOW

No.	Detailed Instructions	Prep.	Time In
1	CHANGE CARDS	2.10	
2	WALK TO TOOL SHED & GET TOOLS	2.00	
3	WALK TO JOB	1.40	
4	CLIMB TO BENCH		.12
5	GET BRUSH		.06
6	BRUSH OFF SASH		.50
7	LOWER SASH (TOP SASH)		.09
8	DUST TOP OF SASH		.11
9	DUST 5 PANES, TWO RAISE SASH		1.62
10	RAISE SASH (3 TIMES ON EA. SASH) .09 x 6		.42
11	GET CAN & WASH		.12
12	WET WASH IN WHITING PANES PANES		.27
13	SMEAR 5 PANES (& THEN LOWER SASH) 25 x 5 x 6 LOWINGS		7.50
14	LOWER SASH (3 TIMES ON EA. SASH) .07 x 6		.42
15	CHANGE WASH		.06
16	DRY 5 PANES (& THEN RAISE SASH)		5.40
17	RAISE SASH (3 TIMES ON EA. SASH)		.42
18	DRY 5 PANES (& THEN LOWER SASH)		8.10
19	LOWER SASH (3 TIMES ON EA. SASH) .07 x 6		.42
20	CLOSE WINDOW		.09
21	MOVE TO NEXT WINDOW WINDOWS		.30
22	WALK TO TOOL SHED & PUT TOOLS AWAY & WALK TO	3.40	26.02
23		8.90 PER WINDOW	6.98
24	TIME PER SQ. FT. 0.9 PREPARATION	3.10 12.00 PER PANE	33.00 1.10
25			
26			
27			

Machine: — Location: DM INSIDE — Instr. Card No.: 3053

When work cannot be done as ordered report must at once be made to man who signed this card. Month 10 Day 12 19.. Signed D.W.

FIG. 81.—INSTRUCTION CARD FOR CLEANING WINDOWS WITHOUT USE OF LADDER

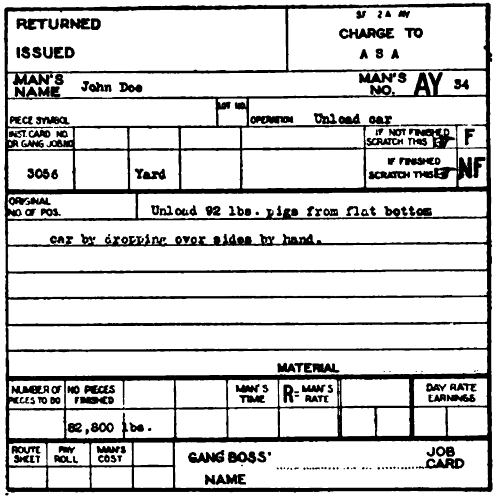


FIG. 82.—FRONT OF JOB CARD FOR A HANDLING OPERATION

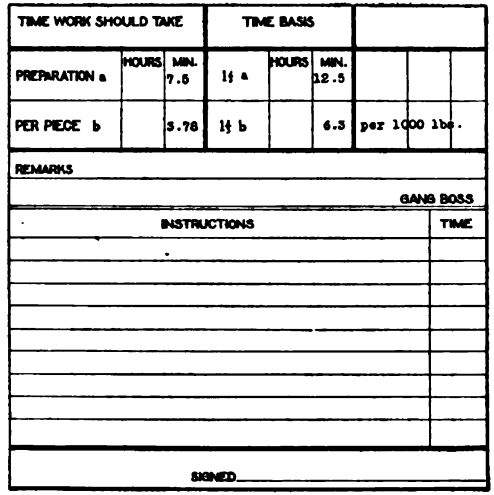
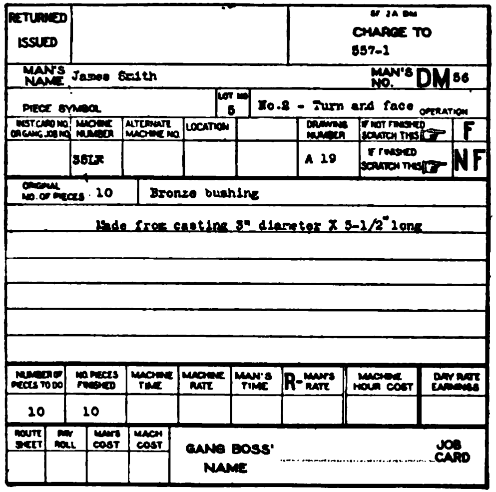


FIG. 83.—BACK OF JOB CARD FOR A HANDLING OPERATION



RETURNED / ISSUED		CHARGE TO 557-1
MAN'S NAME James Smith		MAN'S NO. DM 56
PIECE SYMBOL	LOT NO. 5	No.2 - Turn and face OPERATION

INST CARD NO. OR GANG JOB NO.	MACHINE NUMBER	ALTERNATE MACHINE NO.	LOCATION		DRAWING NUMBER	IF NOT FINISHED SCRATCH THIS ☞ F / IF FINISHED SCRATCH THIS ☞ NF
	36LR				A 19	

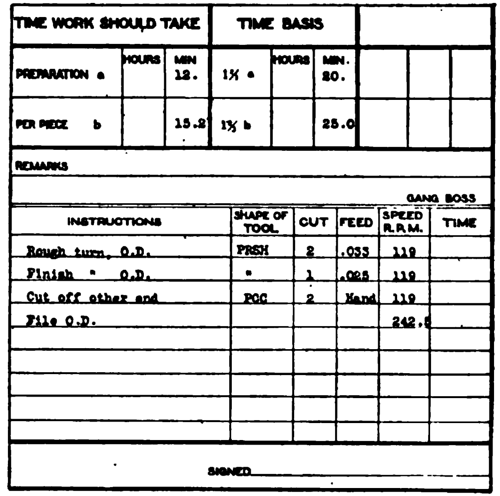
ORIGINAL NO. OF PIECES 10 — Bronze bushing

Made from casting 3" diameter X 5-1/2" long

NUMBER OF PIECES TO DO	NO. PIECES FINISHED	MACHINE TIME	MACHINE RATE	MAN'S TIME	R- MAN'S RATE	MACHINE HOUR COST	DAY RATE EARNINGS
10	10						

ROUTE SHEET	PAY ROLL	MAN'S COST	MACH COST	GANG BOSS' NAME	JOB CARD

FIG. 84.—FACE OF JOB CARD FOR A MACHINING OPERATION



TIME WORK SHOULD TAKE	HOURS	MIN	TIME BASIS	HOURS	MIN.
PREPARATION a		12.	1½ a		20.
PER PIECE b		15.2	1½ b		25.0

REMARKS

GANG BOSS

INSTRUCTIONS	SHAPE OF TOOL	CUT	FEED	SPEED R.P.M.	TIME
Rough turn, O.D.	PRSH	2	.033	119	
Finish " O.D.	"	1	.025	119	
Cut off other end	PCC	2	Hand	119	
File O.D.				242.5	

SIGNED

FIG. 85.—BACK OF JOB CARD FOR A MACHINING OPERATION

INSTRUCTION CARD

	Detail Instructions	Feed	Speeds	Preparation Time	Time Each Piece
1	Change card at window			2.00	
2	Return to work			.50	
3	Select tools			2.00	
	OPERATION "A"				
4	Burr cap with file				.10
	.10 Min. at 55%				.055
5	Move stock to arbor press			1.00	
	OPERATION "B"				
6	Hand cap #21319 on press 19PA				.030
7	Assemble bushing #21687 to cap				.050
8	Press in bushing				.050
9	Land cap in box				.020
	.15 Min. at 50%				.075
10	Get card signed			2.00	
11	Take to window			.50	
				8.00	
	Allowance			2.50	
				10.50	
	Time per piece				0.380

Name or symbol of piece	Oil Pump Drive Shaft Cap Group
Dwg. No.	21301
Operation	Assemble bushing to cap
Oper. No.	1
Mch. No.	313V 19PA
Location	D3M
Preparation P	10.50
Time per piece A	0.38
Premium base time = (P / lot size + A) × 1.66	0.72
Date	12-17-15
Signed	CFT

FIG. 86.—INSTRUCTION CARD FOR AN ASSEMBLY OF AN OIL PUMP DRIVE

INSTRUCTION CARD

	Detail Instructions	Feed	Speeds	Preparation Time	Time Each Piece
1	Change card at window			2.00	
2	Return to work			.50	
3	Select tools			2.00	
4	Cut pins (2 x .036)				.08
5	Land cap in vise				.03
6	Drive two pins				.20
7	Set pins with hammer and punch				.08
8	Land cap in pan (Ream Bushing)				.02
9	Land cap in vise and tighten				.03
10	REAM 7/8" hole				.45
11	Remove cap				.02
12	Test with plug gage #21301(5)				.18
13	Land cap in pan				.02
14	Blow out chips with air 2.00 x 1/20				.10
15	Get card signed			2.00	
16	Take to window			.50	
				7.00	
	Allowance			2.00	
	PREPARATION			9.00	1.21
	1.21 Min. (Handling Time) at 35%				.43
	Time per piece				1.64

Name or symbol of piece	CamShaftBrg.Cap Group
Dwg. No.	21301
Operation	PinBushingAndHand Ream
Oper. No.	3
Mch. No.	313V
Location	D3M
Preparation P	9.00
Time per piece A	1.64
Premium base time = (P / lot size + A) × 1.66	2.81
Date	1/26/17
Signed	CTF

FIG. 87.—INSTRUCTION CARD FOR CAP OF CAM SHAFT BEARING

operation is a standard line of work it is usually unnecessary to give detail instructions as to the procedure in handling the work to a workman who has been in the habit of performing the

INSTRUCTION CARD

	Detail Instructions	Feed		Speeds		Preparation Time	Time each piece
1	Change card at window					2.00	
2	Return to work					.50	
3	Set up machine use fixture #21301 (2)					20.00	
4	Pick up piece and fasten to spindle						.09
5	Adjust tool, start lathe and start to face						.07
6	FACE (9/16" Run)		Hand		2F		.25
7	Move tool, start to turn diameter						.07
8	TURN (Diameter) 3/16" Run		Hand		2F		.11
9	Gage with micrometer						.10
10	Loosen fixture, remove and land in box						.05
11	Sharpen tool and set (5.00 x 1/100)						.05
12	Gage, turn and re-gage (1.31 x 1/20)						.07
13	Get card signed					2.00	
14	Take to window					.50	
						25.00	
						7.50	

Preparation ... | Date 1/26/17 | Signed RPK

Camshaft Brg. Cap Group | 21301
Face and turn cap 4
215 | DM
32.50 | 1.20 | 2 27

.36 Min. (Machine Time Hand Feed) at 20% .07
.50 Min. (Handling Time) at 54% .27
1.20

FIG. 88.—INSTRUCTION CARD FOR HAND-FEED OPERATION ON A CAM-SHAFT BEARING

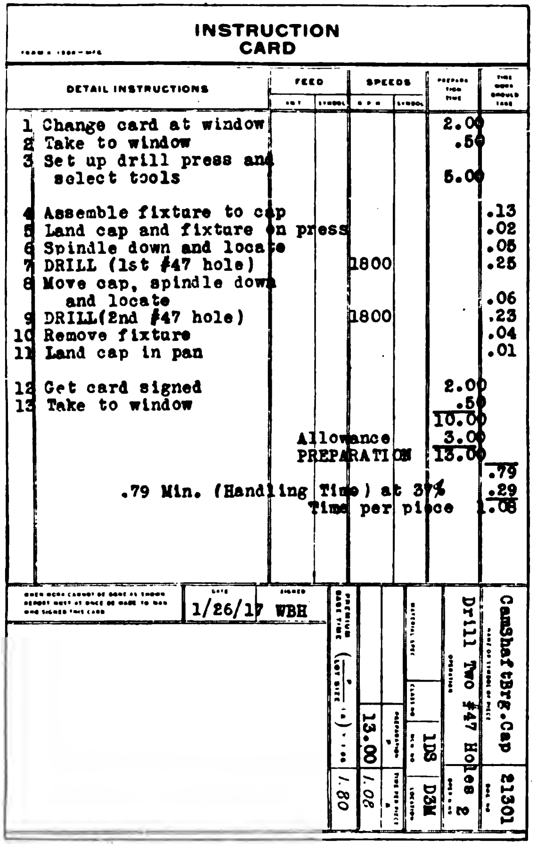
operation, other than the data shown on the back of the card. When the job is given to a new man, however, the number of the standard instruction card for the job should be inserted in the space provided for it on the face of the job card.

The instruction cards shown in Figs 86, 87, 88 and 89 are

for the manufacture of automobile parts at the H. H. Franklin Manufacturing Company, Syracuse, N. Y., and are of particular interest in that the connection between the rate setting from time studies and the setting of Colonel Babcock's ingenious Control Boards is at least indicated by the operation sheet shown in Fig. 90. On the instruction cards proper the fundamental operations, in the sequence in which they have to be performed on the task, are listed, with their respective unit times as obtained from time studies. The speeds for the machine operations and other such necessary mechanical data are recorded, as on all approved instruction cards, and the preparation time separated from the times which the actual productive work should take. To the preparation time an allowance is added to care for permissible delays, the percentage added depending upon the character of the preparatory work. To the time that the actual productive work should take, as established by time studies, an allowance is also added which is dependent upon the percentage of handling time involved. The totals of the preparation time and that the actual productive work should take, so established, become factors in the derivation of the premium base time for the job, upon which the earnings of the workers are calculated. The premium base time is 66⅔ per cent. greater than the task time, or ideal time, and is so entered on the instruction sheet. A strong incentive to better the premium base time is afforded in that for any time the worker saves on such allowance time he is paid for one-half that time at his regular hourly rate.

The use of the rates thus set by time studies in the setting of the Control Boards is quite apparent from the operation sheet shown in Fig. 90. This form, besides giving a concise description of the operation, the location of the machine to be used and the symbol of the machine, carries the information of the time each operation should take, as given by the task, or ideal time on the instruction card, and also the number of days ahead of time the specific operation should be completed to make the particular part available for subsequent assembly or other work. From this complete information on the operation sheet the Control Board can be set up so that a job card can be issued to an operator to start work on the operation with the reasonable certainty that the instruction card will enable him to complete the task within the time allowed by the time study and so assure that smooth progress of work through the shops so necessary for economical and efficient manufacture.

Instruction cards for work of quite another character are

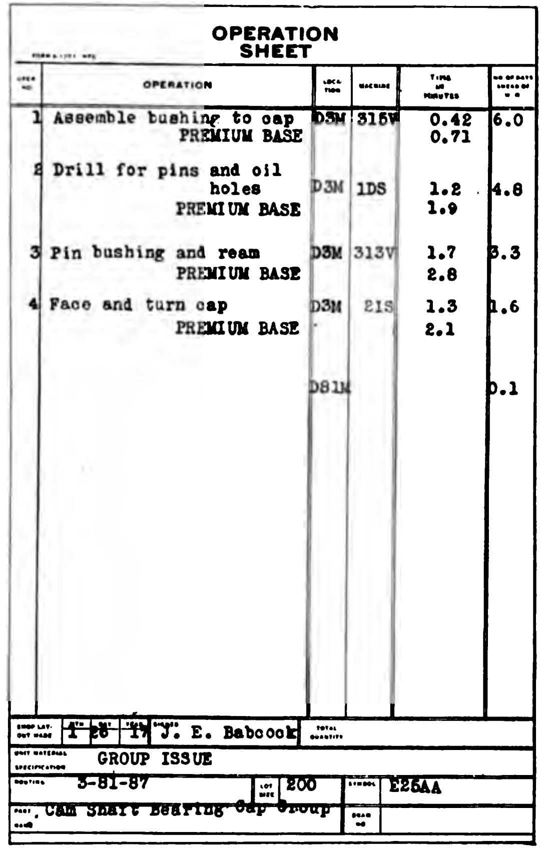


INSTRUCTION CARD

	DETAIL INSTRUCTIONS	FEED	SPEEDS R.P.M.	PREPARATION TIME	TIME EACH PIECE
1	Change card at window			2.00	
2	Take to window			.50	
3	Set up drill press and select tools			5.00	
4	Assemble fixture to cap				.13
5	Land cap and fixture on press				.02
6	Spindle down and locate				.05
7	DRILL (1st #47 hole)		1800		.25
8	Move cap, spindle down and locate				.06
9	DRILL(2nd #47 hole)		1800		.23
10	Remove fixture				.04
11	Land cap in pan				.01
12	Get card signed			2.00	
13	Take to window			.50	
				10.00	
	Allowance			3.00	
	PREPARATION			13.00	.79
	.79 Min. (Handling Time) at 37%				.29
	Time per piece				1.08

DATE	1/26/17
SIGNED	WBH
NAME OF SYMBOL OF PIECE	CamShaftBrg.Cap
DWG. NO.	21301
OPERATION	Drill Two #47 Holes
OPER. NO.	2
MCH. NO.	1DS
LOCATION	D3M
PREPARATION P	13.00
TIME PER PIECE	1.08
PREMIUM BASE TIME	1.80

FIG. 89.—INSTRUCTION CARD FOR DRILLING OPERATION ON A CAM SHAFT BEARING



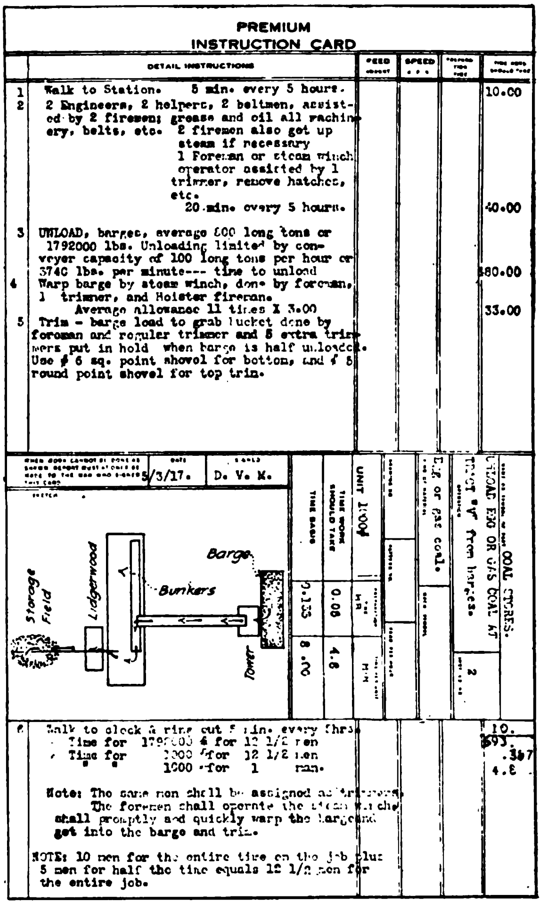
OPERATION SHEET

OPER. NO.	OPERATION	LOCATION	MACHINE	TIME IN MINUTES	NO. OF DAYS AHEAD
1	Assemble bushing to cap PREMIUM BASE	D3M	315V	0.42 0.71	6.0
2	Drill for pins and oil holes PREMIUM BASE	D3M	1DS	1.2 1.9	4.8
3	Pin bushing and ream PREMIUM BASE	D3M	313V	1.7 2.8	3.3
4	Face and turn cap PREMIUM BASE	D3M	21S	1.3 2.1	1.6
		D81M			0.1

SHOP LAY-OUT MADE	1 26 17 J. E. Babcock
UNIT MATERIAL SPECIFICATION	GROUP ISSUE
ROUTING	3-81-87
LOT SIZE	200
SYMBOL	E25AA
PART NAME	Cam Shaft Bearing Cap Group

FIG. 90.—OPERATION SHEET USED AT THE H. H. FRANKLIN MANUFACTURING COMPANY

shown in Figs. 91 and 92, *i. e.*, unloading coal barges at the wharf of the Winchester Repeating Arms Company with the aid of clam-shell bucket-hoisting tower, belt conveyors and—for ground storage—a Lidgerwood cableway. The instruction cards give rates for handling two kinds of coal, and a gang of fifteen men are required to unload a barge, ten of whom are required


PREMIUM
INSTRUCTION CARD

DETAIL INSTRUCTIONS

1 Walk to Station. 5 min. every 5 hours. 10.00
2 2 Engineers, 2 helpers, 2 beltmen, assisted by 2 firemen; grease and oil all machinery, belts, etc. 2 firemen also get up steam if necessary
1 Foreman or steam winch operator assisted by 1 trimmer, remove hatches, etc.
20 min. every 5 hours. 40.00
3 UNLOAD, barges, average 800 long tons or 1792000 lbs. Unloading limited by conveyer capacity of 100 long tons per hour or 3740 lbs. per minute--- time to unload 480.00
4 Warp barge by steam winch, done by foreman, 1 trimmer, and Hoister fireman.
Average allowance 11 times X 3.00 33.00
5 Trim - barge load to grab bucket done by foreman and regular trimmer and 5 extra trimmers put in hold when barge is half unloaded. Use # 6 sq. point shovel for bottom, and # 5 round point shovel for top trim.

5/3/17. D. V. K.

UNIT 100#

0.133 8.00
0.08 4.8
2

6 Walk to clock & ring out 5 min. every 5 hrs. 10.
Time for 1792000 # for 12 1/2 men 1593.
Time for 1000 # for 12 1/2 men .347
" " 1000 # for 1 man. 4.8

Note: The same men shall be assigned as [illegible]
The foremen shall operate the steam winches [illegible] shall promptly and quickly warp the barge and get into the barge and trim.

NOTE: 10 men for the entire time on the job plus 5 men for half the time equals 12 1/2 men for the entire job.

FIG. 91.—INSTRUCTION CARD FOR UNLOADING GAS-COAL BARGES

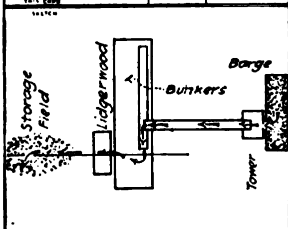
throughout the entire operation. The coal is removed from the barges by the clam-shell bucket and, when about half of the coal has been removed, the five additional men are required to trim the coal from the sides and corners to the center of the barge in order to enable the bucket to close on the coal. The clam shell discharges to a belt conveyor that carries the coal to

a second conveyor, which in turn discharges to any of several coal-pocket compartments. When the coal pocket is filled, the Lidgerwood rig takes coal from them and piles it in an adjacent storage field. Two time studies were taken of the coal-handling plant while in operation, one when unloading egg

PREMIUM
INSTRUCTION CARD

NO.	DETAIL INSTRUCTIONS	FEED	SPEED		
1	Walk to Station. 5min. every 5hours.				10.00
2	2Engineers, 2 helpers, 2beltmen, assisted by 2 firemen, grease and oil all machinery, belts, etc, 2firemen also get up steam if necessary. 1 Foreman or steam winch operator assisted by 1 trimmer, remove hatches, etc. 20min. every 5hours.				40.00
3	UNLOAD, barges, average 800long tons or 1792000lbs. Unloading limited by conveyor capacity of 100long tons per hour or 3740 lbs. per minute.-- time to unload.				480.00
4	Warp barge by steam winch, done by foreman, 1 trimmer, and Hoister fireman. Average allowance 11 times X 3.00				33.00
5	Trim - barge load to grab bucket done by foreman and regular trimmer and 5 extra trimmers put in hold when barge is half unloaded. Use #6sq. point shovel for bottom, and #5round point shovel for top.				

5/3/17 D. V. M.



TIME BASE: 0.111 — $6\frac{3}{4}$ MIN.
TIME WORK SHOULD TAKE: 0.0666 HR. — 4 MIN.
UNIT 1000#
Soft coal
Unloading barges of steam coal at Tract V
1
Coal Stores.

NO.	DETAIL INSTRUCTIONS	FEED	SPEED		
6	Walk to clock & ring out 5 min. every 5hrs.				10.00
	Time for 1792000# for 12 1/2 men				573.
1	" " 1000# " 12 1/2 "				.32
	" " 1000# " 1 man				4.00
	theoretical time per unit in minutes.				
	NOTE: The same men shall be assigned as trimmers. The foreman shall operate the steam winch, shall promptly and quickly warp the barge and get into the barge and trim.				
	NOTE: 10 men for the entire time on the job plus 5 men for half the time equals 12 1/2 men for the entire job.				

FIG. 92.—INSTRUCTION CARD FOR UNLOADING STEAM-COAL BARGES

or gas coal and the other when handling steam coal, instruction cards from which were compiled as illustrated. The nature of the work called for a somewhat different procedure in taking the studies than that which is ordinarily followed in taking time studies of less complex nature, such as the standard pro-

cedure for time studies on operations in a machine shop. Acts or collections of fundamental operations which were found to be common to the work as a whole were grouped, as listed on the instruction cards, and average times taken for group operations, rather than the customary procedure of dividing the work into either elementary or fundamental operations by the various members of the gang and taking time studies of such acts.

A good example of the procedure followed is apparent from a consideration of the second item listed under "General Instructions" on the instruction cards. This item, operation or group of acts is of a preparatory nature and precedes the actual work of unloading a barge. Two engineers, two helpers and two beltmen, assisted by two firemen, oil and grease all the machinery equipment. Two firemen get up steam, if it is necessary, and the foreman of the gang or a steam-winch operator, assisted by one of the men subsequently to be employed to trim the barge, removes the hatches and performs any necessary incidental work on the barge. Obviously all the acts which may at times be necessary to discharge the preparatory work cannot be resolved to a sequence of fundamental operations, in the natural course of events, and more accurate time data can be secured by considering the whole work of preparation as a unit and an average time selected for the task than to take studies on the acts performed by the various individuals. Of course, the average time should be representative of the effective co-operation of the various members of the gang when they are working together and discharging the task efficiently Studies and instructions to the individual men may be necessary before such a condition is realized, but still the study is one of group action in a more or less variable operation rather than a standardized procedure in the performance of a definite task. Averages, rather than times for sequences of correlated fundamental operations, govern the time the work should take.

The times which should be required for the various classified groups of operations listed on the instruction cards were arrived at by similar combinations of time-study procedure and the recording of averages for group times. Times for widely differing activities had to be selected—walking to stations, preparatory operations required before and after unloading, actual unloading, warping the barge, trimming the coal and walking to the clock to ring out.

The rates arrived at for unloading the barges and storing the coal formed a basis for the Halsey premium payment system,

DM 11 SYMBOL

INSTRUCTION CARD FOR OPERATION. 2 M J V 1-1/2 U 1 P

SHEETS, SHEET No.	DRAWING No.	MACHINE No	ORDER No.
2 sheets, sheet No. 1	10017	D 17	M J V 1-1/2 U [redacted]

MATERIAL	CLASS No.	PIECES IN LOT	TIME FOR LOT	BONUS
C. I.	13			

DESCRIPTION OF OPERATION

Bore.

THIS CARD MARKED FROM [redacted]

No.	DETAILED INSTRUCTIONS	FEED	SPEED	ELEMENT TIME PER PIECE	ELEMENT TIME FOR GROUP	ELEMENT TIME FOR PREPARATION
1	Change card				2.50	
2	Study instruction card and drawing				12.00	
3	Put 2 CSP 1x1.3/8x7 on table, 1" face down, 1-3/4" apart				.10	
4	Put CBL 5/8 x 8 in slot				.07	
5	Assemble drills & sleeves				.60	
6	Raise or lower head				.44	
7	Change speed & feed				.16	
8					15.87	
9						
10	Put piece on CSP, counterbore end up			.10		
11	Level up to set lines - all around			.60		
12	Clamp with CBL 5/8 x 8, CCFF-X & CSN 5-1/4"			.32		
13						
14	NOTE: Clamp over exhaust & top of base from side					
15	opposite pilot valve bore.					
16						
17	Put in DJB 2"			.27		
18	Start machine & move head & arm			.20		
19	Countersink end of core central	HF	2 B	.40		
20						
21	Stop machine, change to DDMT 1-7/16" & DSSC 3-4			.39		
22	Start machine			.02		
23	Rough bore to 1-7/16" diameter	.01 B	66.8 2 B	10.45		
24						
25	Stop machine, change to DDMT 1-31/64"			.39		
26	Start machine			.02		
27	Semi-finish bore to 1-31/64" diameter	.01 B	66.8 2 B	10.45		
28						
29	Stop machine & change to DRFU			.39		
30	Start machine			.02		
31	Finish ream 1-1/2" diameter	.064 H	66.8 2 B	1.75		
32	Stop machine, gauge & measure			.30		
33						
34	Change to DSFU 1-1/2"			.37		
35	Put in DCBF 2" & set central				.80	
36	Measure distance from line to top of valve			.38		
37						
38	Start machine			.02		

WHEN MACHINE CANNOT BE RUN AS ORDERED, MACHINE BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS CARD	MONTH	DAY	YEAR	SIGNED	CHECKED
	5	8	13	R	

DM 11

INSTRUCTION CARD FOR OPERATION. 2 M J V 1-1/2 U 1 P — SYMBOL

	DRAWING No.	MACHINE No.	ORDER No.
2 SHEETS, SHEET No. 2	10017	D 17	M J V 1-1/2 U [redacted]

MATERIAL	CLASS No.	PIECES IN LOT	TIME FOR LOT	BONUS
C. I.	13	[redacted]		

DESCRIPTION OF OPERATION

THIS CARD MARKED FROM [redacted]

DETAILED INSTRUCTIONS	FEED	SPEED	ELEMENT TIME PER PIECE	ELEMENT TIME FOR GROUP	ELEMENT TIME FOR PREPARATION
Bore 2" diameter, 2-1/4" deep & distance from line to top of valve	.01 B	66 2 B	3.88	5 A	
Stop machine, gauge and measure			.30		
Change to DSF 1-3/8 x 8			.37		
Put in DCC 20°x1-3/8" & set to chamfer 1-1/2"bore			.30		
Start machine			.02		
Chamfer 1-1/2" bore	HF	2 B	.20		
Stop machine			.02		
Set cutter so that top end of taper is 11/16" from bar			.68		
Start machine			.02		
Bore chamfer in 2" end	HF	2 B	.60		
NOTE:- Bore to depth of finish line.					
Stop machine & take out DSF & DCC			.12		
Loosen & take off clamp			.16		
Take piece off machine & put in tote box			.10		
NOTE:- Stand pieces on end in flat tote boxes. DO NOT pile one on top of another.					
			33.82	.80	
10% on machine time 27.75			2.77		
40% on handling time 6.09			2.44	.32	
			39.03	1.12	
Disassemble 5.00					
Time for lot = (No. pcs. x 39.03) + (5.00 + 1.12 + 15.87)					
Time for 40 pieces = 1583.19 or 264 tenths.					

WHEN MACHINE CANNOT BE RUN AS ORDERED, MACHINE BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS CARD	MONTH	DAY	YEAR	SIGNED	CHECKED
	5	8	13		R.

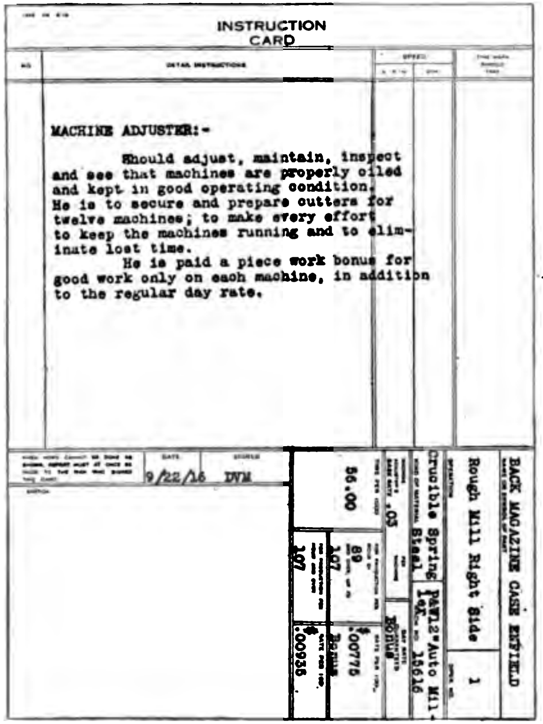
FIG. 93.—INSTRUCTION CARD OF TABOR MANUFACTURING COMPANY

the effect of which upon the speed and economy of handling the coal was quite marked when compared with the former records under day work. When the men were paid at a day-work rate they were more or less dissatisfied with their earnings and made little attempt to exert themselves. The average rate at which the barges were unloaded on day work was 60 long tons per hour. When the men were rated and the premium payment put into effect, the first seven barges were unloaded at an average rate of 87 long tons per hour, an increase of 45 per cent. Since the men have been on rate they have exceeded the set task rate by about 10 per cent. and in consequence have earned about 45 per cent. more than they formerly did on day work.

The instruction card shown in Fig. 93 is an example of a comprehensive form employed at the Tabor Manufacturing Company, Philadelphia, Pa. It is made out for a drilling-machine job, the operation being to bore a part designated by symbols. The operation is the second one on the part and the various elementry operations entailed are listed in consecutive order on the instruction card. Where tools are called for they are designated by symbols and the feeds and speeds for all machine operations are also specified on the instruction card by symbols. The unit times for operations performed only on the job lot and those performed on each individual piece of the lot are kept separate so that the time for the lot or other unit can be calculated readily. The time for the lot or other unit is placed on the instruction card, following the summation of unit times, etc.

At the Tabor Manufacturing Company it is the practice to have instruction cards drawn up in a rough form by an experienced rate setter. These drafts are then turned over to a clerk who ascertains the unit times from recorded and classified time-study data and executes the instruction card in its final form.

A machine adjuster's instruction card used at the Winchester Repeating Arms Company, New Haven, Conn., is illustrated in Fig. 94. This is an example of a piece-work-bonus instruction card where there is in force a plan of bonus payment which will be described in some detail in a subsequent section. Such an instruction card is issued to the machine adjuster caring for the equipment employed for each machine operation, the example illustrated covering the first operation on the back magazine case of an Enfield rifle. The card should carry detailed instructions as to what the machine adjuster should do, the base rate he is to receive for doing it and the bonus he is to receive for


INSTRUCTION CARD

MACHINE ADJUSTER:-

Should adjust, maintain, inspect and see that machines are properly oiled and kept in good operating condition. He is to secure and prepare cutters for twelve machines; to make every effort to keep the machines running and to eliminate lost time.

He is paid a piece work bonus for good work only on each machine, in addition to the regular day rate.

DATE 9/22/16 SIGNED DVM

BACK MAGAZINE CASE ENFIELD

Rough Mill Right Side — OPER. NO. 1

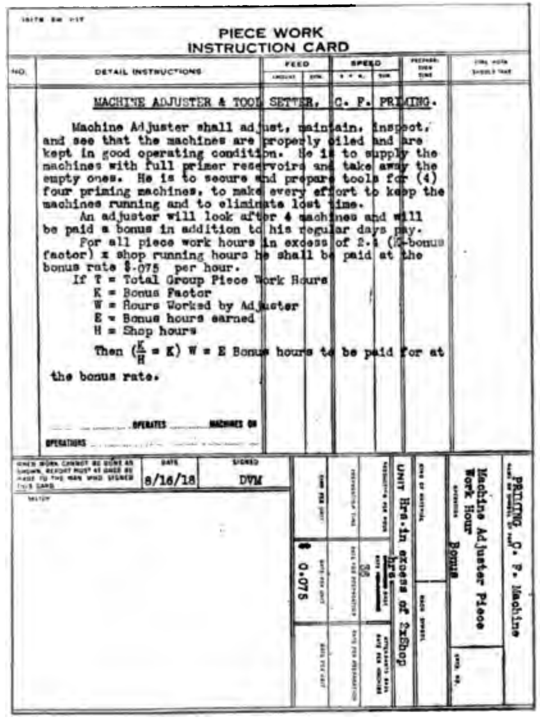
Crucible Spring Steel — P&W 12" Auto Mill 14K No. 15616

BASE RATE .03 — DAY RATE Bonus

TIME PER 1000 56.00 — 89 — 107 — $.00775 Bonus

107 — $.00935

FIG. 94.—INSTRUCTION CARD FOR MACHINE ADJUSTER


PIECE WORK INSTRUCTION CARD

MACHINE ADJUSTER & TOOL SETTER, C. F. PRIMING.

Machine Adjuster shall adjust, maintain, inspect, and see that the machines are properly oiled and are kept in good operating condition. He is to supply the machines with full primer reservoirs and take away the empty ones. He is to secure and prepare tools for (4) four priming machines, to make every effort to keep the machines running and to eliminate lost time.

An adjuster will look after 4 machines and will be paid a bonus in addition to his regular days pay.

For all piece work hours in excess of 2.4 (K-bonus factor) x shop running hours he shall be paid at the bonus rate $.075 per hour.

If T = Total Group Piece Work Hours
K = Bonus Factor
W = Hours Worked by Adjuster
E = Bonus hours earned
H = Shop hours

Then $(\frac{T}{H} - K)$ W = E Bonus hours to be paid for at the bonus rate.

OPERATES ____ MACHINES ON ____

OPERATIONS ____

DATE 8/16/18 SIGNED DVM

PRIMING C. F. Machine

Machine Adjuster Piece Work Hour — Bonus

UNIT Hrs. in excess of 2xShop hrs.

56

$ 0.075

FIG. 95.—INSTRUCTION CARD FOR MACHINE ADJUSTER AND TOOL SETTER

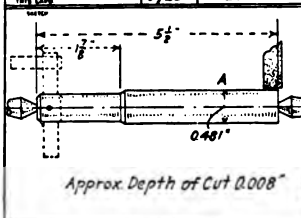
keeping his machines in good running condition and for the amount of good work—which is largely dependent upon the condition of the machine—that is turned out on the machine.

Fig. 95 illustrates a somewhat more complex form of piece-work instruction card issued to the adjuster and tool setter

PREMIUM
INSTRUCTION CARD

NO.	DETAIL INSTRUCTIONS	PREPARATION TIME	TIME WORK SHOULD TAKE
1.	Change ticket at window	2.00	
2	Get work and tools	6.00	
3	Set up machine	9.00	
4	Pick up piece, place on centers		.055
5	Start work and table		.040
6	GRIND A 2 Passes work 200 R.P.M. Table 1st Cone slow 4½" Str. 6.45" per min.		1.350
7	Stop machine and remove piece		.045
8	Allowance for regrinding piece .815x1/15		.052
9	Dress wheel 2.50x1/25		.100
			1.644
10	Have ticket signed by foreman	1.50	
11	Move work to inspection	1.50	
	PREPARATION TIME	20.00	
12	1.350 (Mch.Time) Power Feed at 5%		.068
13	.294 (H'dling Time) #10 Curve at 85%		.250
			1.962
14	Allowance for washing and oiling at 3%		.059
			2.02

DATE	SIGNED
9/28	D.V.M.



Hourly Production 29.7
Time Basis 33.2 Min 3.36 Min
Time Work Should Take 20 Min 2.02 Min
Unit Per Piece
Class #4
Morse #2 (new)
Soft grind body
Card # 104
[illegible] 45 Auto Colt S3

FIG. 96.—PREMIUM INSTRUCTION CARD FOR TOOL DEPARTMENT

caring for a certain number of special machines, also in use at the Winchester Repeating Arms Company. It itemizes the operations the machine adjuster and tool setter is to perform and shows in algebraic form the bonus rate he shall receive for all piece-work hours output in excess of a stipulated amount.

The premium instruction card illustrated in Fig. 96 is of a form used at the Winchester Repeating Arms Company for the department in which the small tools used in the manufacture of regular product are made. It differs from other machine-operation cards principally in that it is for work which is done only occasionally and in relatively small quantities, so that special time studies for rate setting would not be warranted.

The sequence of operations are planned by a skilled rate setter familiar with the type of work and the unit times for the various elementary are obtained from classified records of previous time studies. The work is placed on the Halsey Premium Plan.

DATE	Employee's No. & Name	TOTAL ELAPSED TIME	NO. OF PIECES FINISHED	Averaged Time Per Piece = Y	% MADE = ([illegible]) − ½

FIG. 97.—RECORDING FORM ON BACK OF PREMIUM INSTRUCTION CARD

On the back of the instruction card a recording form is stamped (Fig. 97) for entering the accomplishment under various dates and different workers. The total time elapsed, the number of pieces finished, average time per piece and the percentage of premium made are recorded for each time the job is undertaken. The rate of payment is not placed on the card, as this may vary from time to time.

APPENDIX IV

INSTRUCTION CARDS IN TABULAR FORM

APPENDIX IV

RATE TABLES

INSTRUCTION CARDS IN TABULAR FORM

TIME studies taken of any but very special operations or equipment—even such studies, not infrequently—usually supply very valuable information for much more than the special operation upon which the study was taken. This is particularly true of machine and operation studies in the machine shops of the metal-working industry. The data so secured should invariably be systematically classified, tabulated and filed for reference according to some comprehensive method, such as that described in Appendix II. Such time-study data is invaluable for guide and information in compiling instruction cards and when arranged in suitable form on a data sheet may even serve as instruction cards in tabular form.

This use of rate tables as instruction cards is essentially advantageous when parts are made up in small quantities, the entire number of pieces required taking but a comparatively short time to complete. In such cases it is obvious that if the workmen are to be kept busy they should change their jobs quit frequently. If there is any attempt made to rate the work, there should be provided means by which the workman can secure instructions for his next job with the least possible delay. In order that this may be possible without having a time-study department of an unwarranted size for the number of workmen employed in the shops, the drafting of the necessary instructions to the workmen must be expeditiously done. The compilation of instructions is most readily performed by direct reference to well tabulated rate tables. These tables should be made up in such form as to show the detailed elementary operations and corresponding unit times, or, in other words, in the form of an instruction card embodying a sketch, when possible, to illustrate more clearly the nature of the operation.

Such time and rate tables in tabular form may be classified

under two general headings: 1st, rate tables covering a line of product varying in size but otherwise similar, and 2d, rate tables covering the entire line of work that can be performed on a machine.

An example of the first class of tables would be tabulated rates on a certain line of bronze bushings varying in size from $1\frac{13}{16}$ to 9 inches in diameter, 2 to 7 inches in bore and from 2 to 16 inches in length. In the rough, such bushings are furnished cast with a cored hole and a definite amount of metal left on all dimensions for finishing. A systematic series of machine-time studies on a Warner & Swasey turret lathe for pins and bushings would furnish the data for a rate table of the second class. The variety of work for which this machine is suited is limited and time studies could be taken and rate tables compiled in a comparatively short time that would cover the entire line of work which could be performed on the machine.

Figs. 98 to 104 inclusive illustrate rate tables of the first class and furnish all the data and information necessary for issuing instructions to the workmen to produce a line of standard bronze bushing from the rough-cast state in two operations. The first three tables furnish the data for the first combined operation of boring and facing one end of the bushings and the other four tables the data for the second combined operation of turning and facing the other end of the bushings.

To illustrate the use of these tables in rate setting and the procedure followed in issuing instructions to an operator, it may be assumed that a rate is required for finishing a standard bronze bushing to the dimensions given in Fig. 105 from a rough cored casting, the dimensions of which are also standard and given in the illustration.

Familiarity with the work or reference to the rate tables would indicate that the standard procedure would consist of two operations (combined operations): 1st, boring and facing one end of the casting on a 21-inch Gisholt turret lathe, and 2d, turning and facing the other end of the casting on a 24-inch Reed engine lathe.

Reference to Fig. 98 shows that the task time for boring a 3-inch hole and facing one end of the casting—the length of the finished bushing being 5 inches—would be 16.98 minutes. The number of cuts required and the shape of the tools to be used are also given on the rate table, and in the column for bushings of 3-inch bore are given the speeds and feeds that should be used for the different cuts. The instructions that would be given the operator with his job card for such a task,

OBSERVATIONS OF HAND WORK ON TURRET LATHE 21"

TIME FOR BORING & FACING BUSHING BRONZE

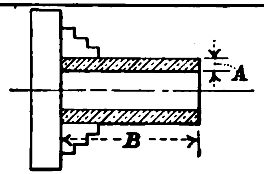
Bushing Boring & Facing

OBSERVER'S NAME, ... MACHINE, Gisholt Turret Lathe No. 10Lt.

WORKMAN'S NAME, ... DATE, ... PIECE, ...

WEIGHT, ... LBS.

NOTE: All Bores 3-1/2" & Under to be Reamed. Bores above 3-1/2" to be Finish Bored. Length of Run for Boring Figured = Length of Finished Bushing 1/4"	DIAM. OF BORE		2"	2-1/4"	2-1/2"	2-3/4"	3"	3-1/2"	4"	4-1/2"	5"	6"	7"
	Face, Rough & Semi-Finish.	Speed	140.5	140.5	140.5	117.3	98.5	82.6	82.6	66.5	55.8	46.75	38.7
		Speed	.0208	.0208	.0208	.0208	.0208	.0208	.0208	.0208	.0208	.0208	.0208
	Ream or Finish.	Speed	46.75	46.75	46.75	38.7	32.5	27.25	27.25	22.7	19.05	16.	19.25
		Speed	.0208	.0208	.0208	.0208	.0416	.0416	.0208	.0208	.0208	.0208	.0208
		Shape of tool	TASK			TIME			IN	MINUTES			
(1) Put Piece in Chuck	OPERATION		0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
(2) Make Run True			--	--	--	--	--	--	--	--	--	--	--
(3) Face "A" 2 Cuts		PRSH	--	--	--	--	--	--	--	--	--	--	--
(4) Rough Bore 1 Cut		DCDS	--	--	--	--	--	--	--	--	--	--	--
(5) Semi-Finish Bore 1 Cut		DCDS	--	--	--	--	--	--	--	--	--	--	--
(6) Ream or Finish Bore 1 Cut		Reamer DRMS Cutter DCDS	--	--	--	--	--	--	--	--	--	--	--
(7) Setting Tools			3.46	3.46	3.46	3.46	3.46	0.46	3.46	3.46	3.46	3.46	3.46
(8) Loosen Chuck & Remove Piece			0.24	0.24	0.24	0.24	0.24	0.24	C.24	0.24	0.24	0.24	0.24



	LENGTH OF BUSHING B	2"	2-1/4"	2-1/2"	2-3/4"	3"	3-1/2"	4"	4-1/2"	5"	6"	7"
X	2"	10.02	10.02	10.02	11.12	10.36	11.36	13.56	16.52	18.70	21.26	21.39
	2-1/2"	10.96	10.96	10.96	12.28	11.33	12.44	15.80	15.80	21.04	24.08	24.16
	3"	11.92	11.92	11.92	13.42	12.30	14.48	17.68	20.49	23.38	26.90	26.94
	3-1/2"	12.85	12.85	12.85	14.55	14.13	15.63	19.26	22.48	25.93	30.42	30.31
	4"	13.77	13.77	13.77	16.61	15.08	16.77	20.88	24.47	28.77	33.25	33.18
	4-1/2"	14.73	14.73	15.63	17.77	16.01	17.92	22.52	27.16	31.11	36.05	35.84
	5"	15.70	16.60	16.60	18.94	16.98	19.06	24.84	29.15	33.46	38.87	38.72
Y	5-1/2"	17.52	17.52	17.52	20.09	17.92	20.90	26.47	31.15	35.80	41.68	41.50
	6"	18.44	18.44	18.44	21.18	19.56	22.05	28.10	33.14	38.14	44.50	44.27
	6-1/2"	19.41	19.41	19.41	22.99	20.52	23.19	29.72	35.13	40.48	47.33	47.04
	7"	20.38	20.38	21.08	24.11	21.47	24.34	31.36	37.12	42.83	50.13	49.81
	8"	22.26	22.95	22.95	26.38	23.35	26.14	33.64	41.10	47.51	55.76	58.24
Z	9"		25.00	25.00	28.60	25.23	27.72	35.70	45.08	52.20	61.40	66.44
	10"			26.80	30.89	27.06	29.53	38.00	49.06	56.89	67.03	74.76
	11"			28.02	33.30	29.04	31.33	40.28	53.04	61.57	72.66	83.08
	12"				35.60	30.91	33.14	42.58	57.02	66.21	78.29	91.39
	13"				37.84	32.78	34.94	44.86	61.01	70.94	83.92	99.71
	14"					34.65	36.74	47.15	64.99	75.63	89.56	108.92
	15"						38.55	49.44	68.97	80.32	95.19	116.45
	16"							51.72	72.96	85.00	100.82	124.77

NOTE: Task Time in this Table = (Minimum Handling Time 50%) (Minimum Machine Time 10%) (Minimum Filing Time+ 25%)

REFERENCE: For Task Time for:
Facing Bushing (Extra Run) See 2-M-8
Putting Radius on Bushing See 2-M-9
X=1.20 Min. Allow. for make run true (Oper. 2)
Y=2.10 " " " " " " "
Z=2.80 " " " " " " "

MADE | REVISED | 2-M-7

FIG. 98.—RATE TABLE

OBSERVATIONS OF HAND WORK ON TURRET LATHE 21"

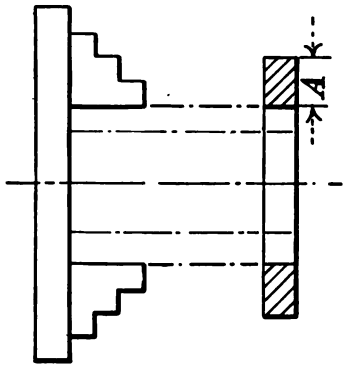
TIME FOR FACING BUSHING-EXTRA LENGTH OF RUN BRONZE.

Bushing Facing

OBSERVER'S NAME, ... **MACHINE,** Gisholt Turret Lathe #10 Lt

WORKMAN'S NAME, ... **DATE,** 8/27/12 **PIECE,** ....

WEIGHT, ... **LBS.**



		FACING FLANGE BUSHINGS EXTRA L'GTH OF RUN							
	SPEED	140.5	117.3	98.5	82.8	66.3	55.8	46.75	38.7
	FEED	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208
		TASK TIME IN MINUTES							
LENGTH "A"	1/4"	0.095	0.113	0.138	0.157	0.199	0.239	0.286	0.338
	1/2"	0.189	0.227	0.275	0.315	0.398	0.477	0.572	0.675
	3/4"	0.284	0.340	0.413	0.472	0.597	0.716	0.858	1.013
	1"	0.378	0.453	0.550	0.628	0.796	0.957	1.144	1.351
	1-1/4"	0.473	0.567	0.688	0.787	0.995	1.194	1.430	1.689
	1-1/2"	0.568	0.680	0.825	0.944	1.195	1.432	1.716	2.026
	1-3/4"	0.662	0.792	0.963	1.101	1.394	1.671	2.002	2.364
	1 2"	0.757	0.906	1.100	1.258	1.593	1.910	2.288	2.702

NOTE:-

This table is task Time for one cut and is figured as an Additional Length of run to operation #3 on 2-M-7

REFERENCE:-

For task time for
Boring & Facing Bushing See 2-M-7
Putting radius on Bushing See 2-M-9

MADE		REVISED			2-M-8

FIG. 99.—RATE TABLE

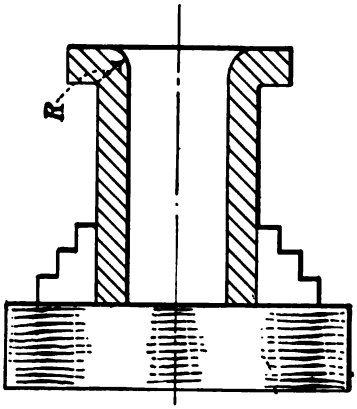
OBSERVATIONS OF HAND WORK ON TURRET LATHE 21"

TIME FOR PUTTING RADIUS ON BUSHING
BRONZE

Bushing Radius

OBSERVER'S NAME, ... **MACHINE,** Gisholt Turret Lathe No. 10Lt.
WORKMAN'S NAME, ... **DATE,** 8/28/12. **PIECE,** ....
WEIGHT, ... **LBS.** ....

(1) RADIUS (Operations)	SPEED	140.5	117.3	98.5	82.6	66.5	55.8	46.75	38.7	32.5	27.25	22.7	19.05
	FEED	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND
(2) SETTING TOOLS		0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
SHAPE OF TOOL	PFRA	TASK TIME IN MINUTES											
RADII "R"	1/8"	0.88	0.93	1.00	1.09	1.21	1.33	1.46	1.65	1.84	2.10	2.39	2.56
	3/16"	1.02	1.11	1.21	1.33	1.51	1.69	1.90	2.17	2.47	2.85	3.31	3.60
	1/4"	1.16	1.28	1.42	1.57	1.82	2.05	2.34	2.70	3.10	3.59	4.22	4.65
	5/16"	1.32	1.46	1.62	1.81	2.13	2.42	2.78	3.23	3.73	4.34	5.13	5.69
	3/8"	1.46	1.64	1.83	2.05	2.44	2.78	3.22	3.76	4.35	5.09	6.04	6.74
	7/16"	1.61	1.81	2.04	2.30	2.75	3.14	3.66	4.29	4.93	5.84	6.96	7.78
	1/2"	1.76	1.99	2.25	2.54	3.05	3.71	4.10	4.81	5.61	6.59	7.87	8.83



NOTE:-
Task Time in this Table =
Minimum Handling Time + 50%
\+ " Machine " + 10%
\+ " Filing " + 25%

Hand Feed = 0.01" per Rev.
Length of Run Figured = RX3

REFERENCE:- For Task Time for
Boring & Facing Bushing See 2-M-7
Facing Bushing (Extra Run) See 2-M-8

MADE	8/28/12	REVISED	9/30/12.					2-M-9

FIG. 100.—RATE TABLE

OBSERVATIONS OF HAND WORK ON LATHE 24"

TIME FOR TURNING & FACING BUSHINGS BRONZE.

Bushing Turning &Facing

OBSERVER'S NAME, ... MACHINE, 35LE REED
WORKMAN'S NAME, ... DATE, 8/26/1912 PIECE, ...
WEIGHT, ... LBS. ....

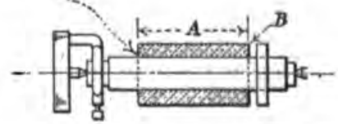
OUTSIDE DIAMETER OF BUSHINGS		1-13/16" up to and incl. 3"			Above 3" up to and incl. 5-1/2"			Above 5-1/2" up to and incl. 7"			Above 7" up to and incl. 9"		
OPERATIONS	Shape of Tool	FEED	SPEED	Task Time in Min	FEED	SPEED	Task Time in Min	FEED	SPEED	Task Time in Min	FEED	SPEED	Task Time in Min
(1) Put Arbor in Piece		--	--	0.66	--	--	1.11	--	--	1.11	--	--	1.14
(2) Put Dog on Arbor		--	--	0.10	--	--	0.14	--	--	0.18	--	--	0.22
(3) Put Arbor on Centers		--	--	0.15	--	--	0.15	--	--	2.35	--	--	2.35
(4) Tighten Set Screw on Dog		--	--	0.09	--	--	0.14	--	--	0.20	--	--	0.27
(5) ROUGH TURN "A" (2 Cuts)	PRSH	0.033	119	--	.0572	62.7	--	.0572	52.2	--	.0572	36.5	--
(6) FINISH TURN "A" (1 Cut)	PRSH	0.025	119	--	0.025	62.7	--	0.025	52.2	--	0.025	36.5	--
CUT OFF OTHER END "B" (2 Cuts)	PCC	Hand .01	119	--	Hand 0.01	62.7	--	Hand 0.01	52.2	--	Hand 0.01	36.5	--
FILE "A"		--	242.5	2.00 to 7.50	--	143	3.00 to 13.55	--	119	4.00 to 15.00	--	89.6	5.00 to 20.00
(9) Setting Tools		--	--	5.25	--	--	5.25	--	--	5.48	--	--	5.48
(10) Loosen Set Screw on Dog		--	--	0.06	--	--	0.07	--	--	0.10	--	--	0.13
(11) Remove Arbor from Centers		---	--	0.07	--	--	0.15	---	--	1.23	--	--	1.23
(12) Remove Arbor from Piece		--	--	0.36	--	--	0.84	--	--	0.92	--	--	0.92
TOTAL HANDLING TIME				6.74			7.85			11.57			11.74
LENGTH "A"	2"			11.12			14.34			19.93			22.98
	3-1/2"			12.63			17.16			23.27			28.13
	5"			15.20			20.13			26.14			33.49
	7"			17.82			23.98			31.44			39.94
	9"			20.40			27.83			36.37			46.86
	12"			23.90			33.72			43.69			52.69
	14"			27.06			38.48			48.16			61.94
	16"			30.78			42.83			52.85			68.88

NOTE: Task Time in this Table =
Minimum Handling Time + 50%
+ " Machine " + 10%
+ " Filing " + 25%

Length of Run for Turning as Figured = A + 1/4"

REFERENCES:
For Task Time for Turning & Facing Flange of Bushing See 1-M and 1-M-3-B: For Filleting See 1-M

This end Finished on Previous Boring Operation



MADE | REVISED | 1-M-1

FIG. 101.—RATE TABLE

neglecting the question of preparation-time allowance, are as follows:

Operation	Shape of Tool	Number of Cuts	R.P.M.	Feed
Face "A"..........	PRSH	2	98.5	0.0208
Rough bore "B"....	DCDS	1	98.5	0.0208
Semi-finish "B".....	DCDS	1	98.5	0.0208
Ream.............	DRMS	1	32.5	0.0416

16.98 minutes

As work of this class becomes more or less standard an experienced operator would require in the way of instructions only the finished dimensions of the bushing and the speeds and feeds for the various cuts.

Should there be a flange on the bushing, similar to that shown on the rate table, Fig. 99, the additional time for the machining operation entailed and full information regarding tools, cuts, speeds and feeds would be obtained from that table. Similarly, in the event of a radius in the base of the bushing as shown in Fig. 100, the task time for forming it and the proper tools, speeds, etc., would be found on Rate Table, 2 M-9.

For the second operation, turning the bushing and facing the other end, the rate table shown in Fig. 101 is used. The task time for the combined operation is given as 20.13 minutes and the table furnishes instructions as to the proper tools, number of cuts required, feeds and speeds. Disregarding the question of preparation-time allowance, the instruction given the workman with his job card would be:

Operation	Shape of Tool	Number of Tool	R.P.M. Cuts	Feed
Rough turn.........	PRSH	2	119	0.033
Finish turn.........	PRSH	1	110	0.025
Cut off.............	PCC	2	119	Hand
File................			242.5	

20.13 minutes

Should there be a flange or fillet on the end last faced, the times for such extra operations, together with the necessary data and information concerning tools, speeds and feeds, would be found on the rate tables shown in Figs. 102, 103 or 104 and the additional time would have to be counted in rating the job.

Rate tables typifying the second class of tables are illustrated in Figs. 106, 107, 108, 109 and 110, which cover the entire line of work that can be done on a certain machine—for instance, the Warner & Swasey turret lathe for making pins and bushings

OBSERVATIONS OF HAND WORK ON LATHE 24"

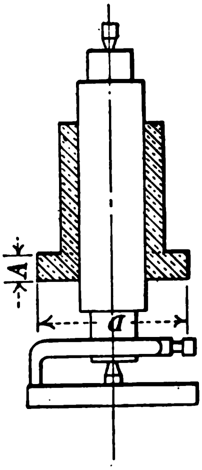
TIME FOR TURNING & FACING FLANGE ON BRONZE BUSHING

Bushing(Flange Turning & Facing Flange.

OBSERVER'S NAME, ______ **MACHINE,** 36 LE REED
WORKMAN'S NAME, ______ **DATE,** 8/28/12. **PIECE,** ______
WEIGHT, ______ **LBS.**

	DIAMETER OF FLANGE "D"		3" up to and Incl. 5-1/2".			Above 5-1/2" up to and Incl. 7"			Above 7" up to and Incl. 9"			Above 9" up to and Incl. 11"		
	OPERATIONS	SHAPE OF TOOL	FEED	SPEED	TASK TIME IN MIN	FEED	SPEED	TASK TIME IN MIN	FEED	SPEED	TASK TIME IN MIN	FEED	SPEED	TASK TIME IN MIN
1	ROUGH TURN "A" (2 Cuts)	PRSH	.033	120	—	.0572	62.7	—	.0572	52.2	—	.0572	36.5	--
2	FINISH TURN "A" (1 Cut)	PRSH	.025	119	—	.025	62.7	--	.025	52.2	—	.25	36.5	--
3	FILE "A"		--	242.5	—	—	143	—	—	119	--	--	89.6	--
4	Setting Tools		--	--	2.30	--	--	2.30	—	—	2.30			2.30
			THICKNESS OF FLANGE "A"	1/4"	2.32			3.01			3.14			3.49
				3/8"	2.95			3.22			3.40			3.86
				1/2"	3.06			3.41			3.60			4.17
				5/8"	3.20			3.60			3.96			4.54
				3/4"	3.35			3.82			4.10			4.89
				7/8"	3.47			4.02			4.57			5.26
				1"	3.53			4.24			4.61			5.62
				1-1/4"	3.92			4.64			5.10			6.28
				1-1/2"	4.18			5.03			5.57			6.94

NOTE: Task Time in This Table=
Minimum Handling Time 50%
" Machine " 10%
" Filing " 25%



REFERENCE: For Task Time
For Turning & Facing Bushing See 1-M-1
For Facing Flange of Bushing See 1-M-3
For Filleting Bushing See 1-M-4-B

MADE	8/29/12	REVISED	9/18/12.					1-M-2

FIG. 102.—RATE TABLE

OBSERVATIONS OF HAND WORK ON LATHE 24"

TIME FOR FACING FLANGE ON BUSHING
BRONZE

Bushings
Facing
Flanges

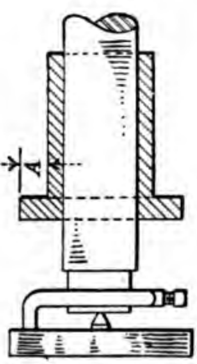
OBSERVER'S NAME, ______ MACHINE, 35 LE REED
WORKMAN'S NAME, ______ DATE, 8/27/12. PIECE, ______
WEIGHT, ______ LBS.

OPERATIONS.	"A"	1/2"				3/4"				1"				1-1/4"			
	SPEED	119	62.7	52.2	36.3	119	62.7	52.2	36.5	119	62.7	62.7	36.5	119	62.7	52.2	36.5
	FEED	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125
	SHAPE OF TOOL	TASK TIME IN MINUTES.															
(1) ROUGH FACE "A" (1Cut)	PCC	0.43	0.38	1.06	1.52	0.68	1.32	1.58	2.28	0.75	1.39	1.68	2.42	0.90	1.74	2.09	3.02
(2) FINISH FACE "A" (1Cut)	PCC	0.46	0.38	1.06	1.52	0.68	1.32	1.58	2.28	0.75	1.39	1.68	2.42	0.90	1.74	2.09	3.02
(3) Setting Tools		2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.53	2.33	2.33	2.33	2.33	2.33	2.33	2.33
TOTAL		3.25	4.09	4.45	5.37	3.59	4.97	5.49	6.89	3.33	5.11	5.69	7.17	4.13	5.81	6.51	8.37

OPERATIONS.	"A"	1-1/2"				1-3/4"				2"			
	SPEED	119	62.7	52.2	36.5	119	62.7	52.2	36.5	119	62.7	52.2	36.5
	FEED	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125	.0125
	SHAPE OF TOOL	TASK TIME IN MINUTES											
(1) ROUGH FACE "A" (1 Cut)	PCC	1.10	2.09	2.53	3.63	1.29	2.42	2.95	4.23	1.48	2.77	3.37	4.34
(2) FINISH FACE "A" (1Cut)	PCC	1.10	2.09	2.53	3.63	1.29	2.42	2.95	4.23	1.48	2.77	3.37	4.34
(3) Setting Tools		2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33
TOTAL		4.53	6.51	7.39	9.59	4.91	7.17	8.23	10.79	5.29	7.87	9.07	12.01

NOTE:- Task Time in this Table=
Minimum Handling Time + 50%
+ " Machine " + 10%
+ " Fixing " + 25%
Hand Feed= 0.01"

REFERENCE:
For Task Time for Turning & Facing Bushings See 1-M-1
" " " " " " Flanges " 1-M-2
" " " " Filleting Bushings " 1-M-4



MADE | REVISED | 1-M-3

FIG. 103.—RATE TABLE

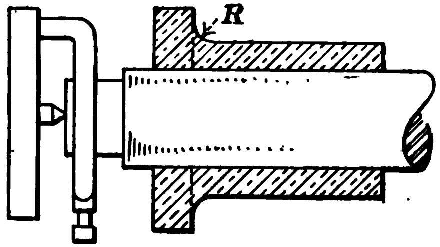
OBSERVATIONS OF HAND WORK ON LATHES — Bushing Filleting

TIME FOR FILLETING BUSHING BRONZE

OBSERVER'S NAME, ______ **MACHINE,** 35 LE REED
WORKMAN'S NAME, ______ **DATE,** 8/27/12 **PIECE,** ______
WEIGHT, ______ **LBS.**

OPERATIONS	"R"	1/8"				3/16"				1/4"		
	SPEED	119	52.2	36.5	18.05	119	52.2	36.5	18.05	52.2	36.5	18.05
	FEED	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND
	SHAPE OF TOOL	TASK TIME IN MINUTES										
(1) FILLETING	PFAD	0.35	0.79	1.13	2.31	0.52	1.17	1.70	3.41	1.58	2.25	3.95
(2) Setting Tools		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.30	1.20	1.20
TOTAL		1.55	1.99	2.33	3.51	1.72	2.37	2.90	4.61	2.78	3.45	5.15

OPERATIONS	"R"	5/16"			3/8"		7/16"		1/2"
	SPEED	52.2	36.5	18.05	36.5	18.05	36.5	18.05	18.05
	FEED	HAND	HAND	HAND	HAND	HAND	HAND	HAND	HAND
	SHAPE OF TOOL	TASK TIME IN MINUTES							
(1) FILLETING	PFRD	1.95	2.64	3.85	2.97	4.51	3.74	5.39	7.16
(2) Setting Tools		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.80
TOTAL		3.15	3.84	5.05	4.17	5.71	4.94	6.59	8.30



NOTE: Task Time In This Table=
Minimum Handling Time + 50%
+ " Machine " + 10%
+ " Filing " + 25%
Hand Feed= 0.01"
Length of Run Figured= RX3

REFERENCE: For Task Time for:
Turning & Facing Bushings See 1-M-1
" " " Flanges of Bushings See 1-M-2 + 1-M-3

MADE 8/11/12 **REVISED** | 1-M-4

FIG. 104.—RATE TABLE

from bar stock not more than 38½ inches long and limited in section to 4⅛ inches in diameter for round stock or 3⅛ inches in short diameter for hexagonal stock. The use of the tables for rate setting and the form of the instructions issued to the workmen for a particular task may be best illustrated by considering a specific example, for instance, establishing the time

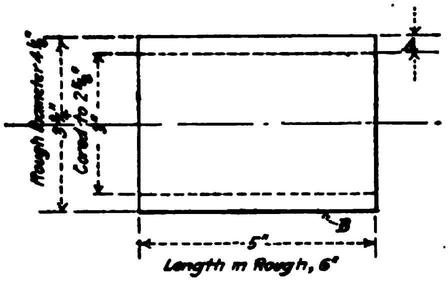


FIG. 105.—STANDARD BRONZE BUSHING

it should take to cut a headed pin from bar stock of machinery steel, such as diagrammatically shown in Fig. 112.

The type of pin is also illustrated on Rate Table 2 M-1, Fig. 106, on which the task time for cutting a pin of the dimensions given, from machinery steel at the proper speed for the material —70 feet per minute—and employing the approved feeds, is given as 26.75 minutes. This rate calls for the turning of the pin in one cut, and chamfering and parting with hand feed. The necessary instructions for performing the task required by the experienced workman, familiar with the machine employed, etc., would simply be:

Turn......	47.8	R.P.M.	0.01	Feed
Chamfer...	47.8	"	Hand	"
Part......	47.8	"	"	"

26.75 minutes per piece.

Should rates be required for other forms of pins, such as those illustrated on other of the rate tables, the task time for the additional operations and the information as to speeds and feeds would be taken from the rate tables on which the desired form of pin was depicted and the task time added to that for cutting the simple pin of the same over-all dimensions illustrated on Rate Table 2 M-1.

The necessity of referring to more than one rate table to find the task time for the more complicated forms draws attention to a very important consideration in making up serviceable

OBSERVATIONS OF HAND WORK ON 3 LT

TIME FOR TURNING & PARTING PINS

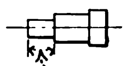
OBSERVER'S NAME, D.V.Merrick MACHINE, "Warner & Swasey" Turret Lathe 116-3 LT
WORKMAN'S NAME, Cheney DATE,
WEIGHT, Max Capacity {4-1/8" Round, 3-1/2" Hex., 38-1/2" Long}

DIAMETER OF STOCK FOR		1-1/8" to 3-1/4"	3-1/4" to 4"				
BRONZE 119 FT.		1-1/8" to 3-1/4"	3-1/4" to 4"				
MACHINE STEEL 70 FT.		1-1/2" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"		
HARD STEEL 50 FT.			1-1/2" to 1-23/32"	1-23/32" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"
SPEED IN R. P. M.		139.5	114.8	90.8	74.3	58.5	47.8
OPERATIONS	Shape of Tool	X	X	X	X	X	X
1 Run Stock up to Stop		0.45	0.45	0.45	0.45	0.45	0.45
2 Turret Back, Turn & Up		0.20	0.20	0.20	0.20	0.20	0.20
3 Start Cut (1/4" Run-Feed 0.035)		0.64	0.78	0.98	1.20	1.53	1.86
4 Turn "A" (C Feed = 0.0100)							
5 Do. # 2		0.20	0.20	0.20	0.20	0.20	0.20
6 Chamfer "B"		0.12	0.13	0.14	0.15	0.16	0.17
7 Turret Back & Turn		0.12	0.12	0.12	0.12	0.12	0.12
8 Run Tool Post Up to Cut, Feed In		0.27	0.27	0.27	0.27	0.27	0.27
9 Part at "C" (Feed 0.00513		1.73	2.95	3.97	5.70	6.90	9.05
10 Tool Post Central		0.14	0.14	0.14	0.14	0.14	0.14
11 Add Stock (Every 10 Pieces)	Length of "A"	0.57	0.57	0.57	0.57	0.57	0.57
TOTAL HANDLING TIME CONST. MACH. TIME		4.44	5.81	7.04	9.00	9.54	12.96
X= TIME WORK SHOULD TAKE	1-1/2"	5.63	7.26	8.85	11.21	12.38	16.40
	1-3/4"	5.83	7.50	9.15	11.58	12.83	16.98
	2"	6.02	7.74	9.45	11.95	13.30	17.55
	2-1/4"	6.22	7.98	9.76	12.32	13.77	18.13
	2-1/2"	6.42	8.22	10.06	12.69	14.24	18.70
	2-3/4"	6.62	8.46	10.36	13.06	14.71	19.28
	3"	6.81	8.70	10.67	13.43	15.18	19.85
	3-1/2"	7.21	9.18	11.27	14.17	16.12	21.00
	4"	7.60	9.66	11.88	14.91	17.06	22.15
	4-1/2"	8.00	10.14	12.48	15.65	18.00	23.30
	5"	8.40	10.62	13.09	16.39	18.94	24.45
	5-1/2"	8.79	11.10	13.69	17.13	19.88	25.60
	6"	9.19	11.58	14.30	17.87	20.82	26.75
	6-1/2"	9.58	12.06	14.90	18.61	21.76	27.90
	7"	9.98	12.54	15.51	19.35	22.70	29.05
	7-1/2"	10.38	13.02	16.11	20.09	23.64	30.20
	8"	10.77	13.50	16.72	20.83	24.58	31.35
	8-1/2"	11.17	13.98	17.32	21.57	25.52	32.50
	9"	11.56	14.46	17.93	22.31	26.46	33.65
	9-1/2"	11.95	14.94	18.53	23.05	27.40	34.80
	10"	12.35	15.42	19.14	23.79	28.34	35.95
	10-1/2"	12.74	15.90	19.74	24.53	29.28	37.10
	11"	13.13	16.38	20.35	25.27	30.22	38.25
	11-1/2"	13.53	16.86	20.95	26.01	31.16	39.40
	12"	13.92	17.34	21.56	26.75	32.10	40.55

SPEEDS

SYMBOL	R.P.M.	SYMBOL	R.P.M.
1 B S	47.8	2 B F	90.8
1 B F	58.5	3 B S	114.8
2 B S	74.3	3 B F	139.8

NOTE

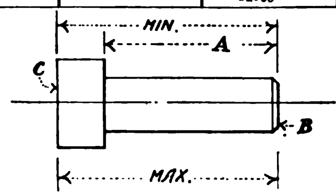


If a second journal - thus has to be turned, add to above time in

2-M-2-P

For threading, add time in

2-M-3-P



MADE REVISED 2-M-1

FIG. 106.—RATE TABLE

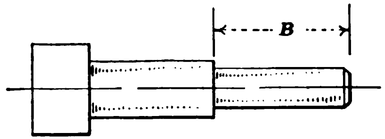
OBSERVATIONS OF HAND WORK ON 3LT.

TIME FOR JOURNALING PINS.

OBSERVER'S NAME D. V. Merrick MACHINE "Warner & Swasey" Turret Lathe 114- 3LT.

WORKMAN'S NAME Cheney DATE Max. Capacity {4-1/2" Round, 3-1/[illegible]" Hex., 30-1/2" Long

WEIGHT LBS.



DIAMETER OF STOCK FOR							
BRONZE 110 Ft.		1-1/2" to 3-1/4"	2-1/4" to 4"		2-7/8" to 4"		
MACH STEEL 70 Ft.		1-1/2" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"			
HARD STEEL 50 Ft.			1-1/2" to 1-23/32"	1-23/32" to 2-1/4"	2-1/4" to 2-7/8"	2-3/4" to 3-3/8"	3-3/8" to 4"
SPEED IN R.P.M.		139.5	114.8	47.8	71.3	58.5	47.8
OPERATIONS	SHAPE OF TOOL	X	X	X	X	X	X
(1) Turret Back, Turn & Jo.		0.20	0.20	0.20	0.20	0.20	0.20
(2) START CUT 1/8" Run		0.32	0.39	0.49	0.10	0.77	0.93
(3) TURN "B" (c Feed=.0100)							
TOTAL HANDLING TIME CONST. EACH PIECE		0.52	0.59	0.69	0.30	0.97	1.13
X= TIME WORK SHOULD TAKE	LENGTH OF "B"						
	1-1/2"	1.71	2.04	2.50	3.01	3.79	4.57
	1-3/4"	1.91	2.28	2.80	3.36	4.26	5.15
	2"	2.10	[illegible]	3.10	[illegible]	4.73	5.72
	2-1/4"	2.30	2.73	3.41	4.12	5.20	6.30
	2-1/2"	2.50	3.00	3.71	[illegible]	5.67	6.87
	2-3/4"	2.70	[illegible]	4.01	4.84	6.14	7.45
	3"	2.90	3.48	4.32	5.23	6.61	8.02
	3-1/2"	3.20	3.96	4.92	5.72	7.55	9.17
	4"	3.50	4.44	5.52	6.71	8.49	10.32
	4-1/2"	4.08	4.92	6.13	7.45	9.43	11.47
	5"	4.40	5.40	6.74	8.19	10.37	12.62
	5-1/2"	4.87	5.88	7.34	8.93	11.31	13.77
	6"	5.27	6.36	7.95	9.67	12.25	14.92
	6-1/2"	5.66	6.84	8.55	10.41	13.19	16.07
	7"	6.06	7.32	9.16	11.15	14.13	17.22
	7-1/2"	6.46	7.80	9.76	11.89	15.07	18.37
	8"	6.87	8.28	10.37	12.63	16.01	19.52
	8-1/2"	7.25	8.76	10.97	13.37	16.95	20.67
	9"	7.64	9.24	11.58	14.11	17.89	21.82
	9-1/2"	8.03	9.72	12.18	14.85	18.83	22.97
	10"	8.43	10.20	12.79	15.59	19.77	24.12

SPEEDS			
SYM	R.P.M.	SYM	R.P.M.
1PS	47.8	2BF	90.0
1BF	58.5	3PS	114.8
2PS	74.3	3BF	139.5

MADE REVISED 2-M-2

FIG. 107.—RATE TABLE

CLASSIFICATIONS OF HAND WORK ON

TIME FOR

ALL CUTS UP & BACK	LENGTH OF "B"	SAP=38.9	SAS=32.05	TAP=26.33	TAS=21.73	TAP=16.32	TAS=13.35
		X	X	X	X	X	X
1-1/2" to 1-5/8" D. FIG. on 1-1/2" (DOUBLE CUT)	2"	1.78	2.25	2.69	3.33	3.84	4.38
	2-1/2"	2.10	2.46	3.02	3.59	4.43	[illegible]
	3"	2.44	2.87	3.53	4.22	[illegible]	[illegible]
	3-1/2"	2.74	3.29	4.07	4.88	[illegible]	[illegible]
	4"	3.12	3.70	4.57	5.49	6.88	[illegible]
	5"	3.79	4.52	5.61	6.77	[illegible]	[illegible]
	6"	4.47	5.34	6.65	8.03	10.11	12.27
	7"	5.15	6.17	7.69	9.31	[illegible]	[illegible]
	8"	5.83	7.00	8.73	10.58	[illegible]	[illegible]
1-3/4" to 2-1/4" D. FIG. ON 1-3/4" (DOUBLE CUT)	2"	1.53	1.78	2.14	2.52	[illegible]	[illegible]
	2-1/2"	1.82	2.12	2.57	3.05	3.77	[illegible]
	3"	2.10	2.46	3.00	3.58	4.44	[illegible]
	3-1/2"	2.38	2.80	3.44	4.11	5.12	6.18
	4"	2.66	3.15	3.87	4.64	5.79	[illegible]
	5"	3.23	3.83	4.74	5.70	7.14	[illegible]
	6"	3.79	4.52	5.61	6.76	8.49	10.29
	7"	4.36	5.21	6.48	7.82	9.83	[illegible]
	8"	4.92	5.90	7.35	8.88	11.18	13.58
2-1/2" to 3" Diam. FIGURED ON 2-1/2" (DOUBLE CUT)	3"	1.76	2.05	2.49	2.95	3.64	[illegible]
	3-1/2"	1.98	2.32	2.84	3.37	4.18	4.97
	4"	2.21	2.60	3.18	3.79	4.71	5.61
	5"	2.66	3.15	3.87	4.65	5.80	6.92
	6"	3.11	3.70	4.57	5.49	6.87	8.27
	7"	3.57	4.26	5.26	6.35	7.95	9.54
	8"	4.02	4.80	5.96	7.09	9.03	10.85
	9"	4.47	5.34	6.65	8.03	10.11	12.27
	10"	4.92	5.89	7.35	8.88	11.18	13.58
	11"	5.38	6.4[illegible]	8.05	9.73	12.07	14.74

		X	Z
1	Turret Back, Turn & Up	0.20	0.33
2	THREAD		
3	Set Die	0.20	0.33
4	THREAD		

	If Grooving for Thd. is Necessary, Add to Above	X	Z
1	Turret Back, Turn & Up.	0.20	0.33
2	GROOVING	0.25	0.42
	TOTAL	0.45	0.75

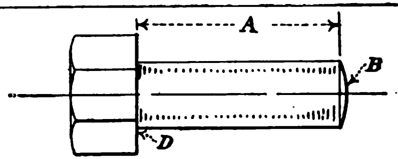
MADE | REVISED | 2-M-3

FIG. 108. RATE TABLE

OBSERVATIONS OF HAND WORK ON 3LT

TIME FOR TURNING FORGED HEX. HEAD BOLTS

OBSERVER'S NAME D. V. Merrick MACHINE "Warner & Swasey" Turret Lathe-116-3LT.
WORKMAN'S NAME Cheney DATE Max. Capacity 4-1/8" Round 3-1/2" Hex. 38-1/2" Long.
WEIGHT LBS.



DIAMETER OF STOCK FOR							
Bronze 110 Ft.		1-1/2" to 3-1/4"	3-1/4" to 4"				
Mach. Steel 70 Ft.		1-1/2" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"		
Hard Steel 50 Ft.			1-1/2" to 1-23/32"	1-23/32" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"
SPEED IN R. P. M.		139.5	114.8	90.8	74.3	58.5	47.8
OPERATIONS	SHAPE OF TOOL	X	X	X	X	X	X
1 Put Bolt in Collet & Tighten		0.45	0.45	0.45	0.45	0.45	0.45
2 Make Run True		0.27	0.27	0.27	0.27	0.27	0.27
3 Turret Back, Turn & Up		0.20	0.20	0.20	0.20	0.20	0.20
4 START CUT (1/4" Run, Feed .0035)		0.64	0.78	0.98	1.20	1.54	1.88
5 TURN "A" (Feed=.0100)							
6 Tool Post Up, Feed In		0.27	0.27	0.27	0.27	0.27	0.27
7 SQUARE CORNER "D" (Feed .00513)		1.38	1.68	1.94	2.17	2.40	1.83
8 Tool Post Central		0.20	0.20	0.20	0.14	0.14	0.14
9 Do. #3		1.25	1.51	1.91	0.20	0.20	0.20
10 ROUND "B" (1/4" Run-Feed .0016)		0.12	0.12	0.12	2.32	2.95	3.63
11 Turret Back & Turn		0.21	0.21	0.21	0.12	0.12	0.12
12 Remove Bolt from Collet					0.21	0.21	0.21
TOTAL HANDLING TIME CONST. MACH. TIME		5.13	5.63	6.69	7.55	8.75	8.90
X=TIME WORK SHOULD TAKE	1-1/2"	6.31	7.37	8.50	9.77	11.57	12.35
	1-3/4"	6.51	7.51	8.81	10.14	12.04	12.92
	2"	6.71	7.75	9.11	10.51	12.51	13.50
SPEEDS	2-1/4"	6.90	7.99	9.41	10.88	12.98	14.07
SYMBOL R.P.M. SYMBOL R.P.M.	2-1/2"	7.10	8.23	9.72	11.25	13.45	14.65
1BS 47.8 2BF 90.8	2-3/4"	7.30	8.47	10.02	11.62	13.92	15.22
1BF 58.5 3BS 114.8	3"	7.49	8.71	10.32	11.99	14.39	15.80
2BS 74.3 3BF 139.5	3-1/2"	7.88	9.19	10.93	12.73	15.33	15.01
NOTE: In Times Shown Below Heavy Line, Operations 6,7,8 are Omitted, As These are done at Same Time as Operation 5.	4"	8.28	9.67	11.53	10.89	13.46	16.16
	4-1/2"	6.88	8.06	9.79	11.63	14.40	17.31
	5"	7.28	8.54	10.39	12.37	15.34	18.46
	5-1/2"	7.67	9.02	11.00	13.11	16.28	19.61
	6"	8.07	9.50	11.60	13.85	17.22	20.76
	6-1/2"	8.46	9.98	12.21	14.59	18.16	21.91
	7"	8.86	10.46	12.81	15.33	19.10	23.06
For Threading, Add to Above Time In—— 2-M-3	7-1/2"	9.25	10.94	13.42	16.07	20.04	24.21
	8"	9.64	11.42	14.02	16.81	20.98	25.36
	8-1/2"	10.03	11.90	14.63	17.55	21.92	26.51
	9"	10.43	12.38	15.23	18.29	22.86	27.66
	9-1/2"	10.82	12.86	15.84	19.03	23.80	28.81
	10"	11.22	13.34	16.44	19.77	24.74	29.96
	10-1/2"	11.61	13.82	17.05	20.51	25.68	31.11
	11"	12.00	14.30	17.66	21.45	26.62	32.26
	11-1/2"	12.39	14.78	18.27	21.99	27.56	33.41

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FIG. 109.—RATE TABLE

OBSERVATIONS OF HAND WORK ON 3 LT

TIME FOR DRILLING AND PARTING BUSHINGS

OBSERVER'S NAME, D. V. Merrick MACHINE, "Warner & Swasey" Turret Lathe 116-3 LT

WORKMAN'S NAME, Cheney DATE, Max Capacity {4-1/8" Round, 3-1/2" Hex., 38-1/2" Long.

WEIGHT, LBS.

DIAMETER OF BORE FOR	Bronze	9/16" to 2-3/4"	2-3/4" to 3-1/2"				
	Mach. Steel	9/16" to 1-3/4"	7/8" to 2-1/4"	1" to 2-7/8"	1-3/8" to 3-1/2"		
	Hard Steel		9/16" to 1-1/4"	7/8" to 1-3/4"	7/8" to 2-1/4"	1" to 2-7/8"	1-3/8" to 3-1/2"
DIAMETER OF STOCK FOR	Bronze 110 Ft.	1-1/2" to 3-1/4"	3-1/4" to 4"				
	Mach. Steel 70 Ft.	1-1/2" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"		
	Hard Steel 50 Ft.		1-1/4" to 1-23/32"	1-23/32" to 2-1/4"	2-1/4" to 2-3/8"	2-3/4" to 3-3/8"	3-3/8" to 4"
SPEED IN R.P.M.		139.5	114.8	90.8	74.3	58.5	47.8
OPERATIONS.	SHAPE OF TOOL	X	X	X	X	X	X
1 Run Stock up to Stock.		0.45	0.45	0.45	0.45	0.45	0.45
2 Turret Back, A up.		0.20	0.20	0.20	0.20	0.20	0.20
3 DRILL ("A" Feed=.0100).							
4 Turret Back & Turn.		0.12	0.12	0.12	0.12	0.12	0.12
5 Run Tool Post up to Cut, Feed In.		0.27	0.27	0.27	0.27	0.27	0.27
6 PART AT "C" ("b" Feed=.00513).		1.34	1.75	2.21	3.79	4.36	5.35
7 Tool Post Central.		0.14	0.14	0.14	0.14	0.14	0.14
8 Add Stock (Every 10 Pieces).		0.37	0.57	0.57	0.57	0.57	0.57
TOTAL HANDLING TIME CONST. MACH.	TIME.	3.09	3.50	3.96	5.54	6.11	7.10
X=TIME WORK SHOULD TAKE	LENGTH OF "A"						
	1-1/2"	4.28	4.95	5.78	7.77	8.93	10.57
	1-3/4"	4.50	5.19	6.08	8.15	9.40	11.15
	2"	4.71	5.43	6.39	8.52	9.87	11.73
	2-1/4"	4.92	5.67	6.69	8.89	10.34	12.31
	2-1/2"	5.14	5.91	6.99	9.26	10.81	12.89
	2-3/4"	5.36	6.15	7.29	9.63	11.28	13.47
	3"	5.57	6.39	7.59	10.00	11.75	14.04
	3-1/2"	5.95	6.87	8.20	10.75	12.70	15.21
	4"	6.32	7.36	8.82	11.49	13.65	16.37
	4-1/2"	6.70	7.84	9.43	12.23	14.60	17.54
	5"	7.07	8.33	10.05	12.97	15.55	18.70
	5-1/2"	7.45	8.81	10.66	13.72	16.50	19.87
	6"	7.83	9.30	11.27	14.46	17.40	21.03
	6-1/2"	8.21	9.78	11.88	15.20	18.40	22.19
	7"	8.59	10.26	12.49	15.94	19.35	23.35
If Spotting is Necessary, Add to Above For Length of Run.							
1 Turret Back, Turn & up.		0.20	0.20	0.20	0.20	0.20	0.20
2 SPOT (Hand Feed=.0065).		0.82	1.26	2.02	3.03	4.54	6.31
TOTAL.		1.02	1.46	2.22	3.23	4.74	6.51

SPEED

SYMBOL	R. P. M.	SYMBOL	R. P. M
1BS	47.8	2BF	90.8
1BF	58.5	3BS	114.8
2BS	74.3	3BF	139.5

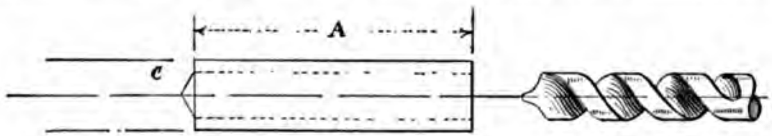

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FIG. 110.—RATE TABLE

OBSERVATIONS OF HAND WORK ON 3LT

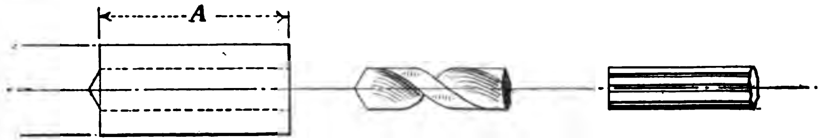
TIME FOR DRILLING OR REAMING

OBSERVER'S NAME D. V. Merrick MACHINE "Warner & Swasey" Turret Lathe 116-3LT

WORKMAN'S NAME Cheney DATE

WEIGHT LBS.

Max Capacity (4-1/8" Round, 3-1/2" Hex., 38-1/2" Long.



DIAMETER OF BORE FOR							
Bronze 110 Ft.		1-1/2" to 3-1/4"	3-1/4" to 4"				
Mach. Steel 70 Ft.		1-1/2" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4" to 3-3/8"	3-3/8" to 4"		
Hard Steel 50 Ft.			1-1/2" to 1-23/32"	1-23/32" to 2-1/4"	2-1/4" to 2-3/4"	2-3/4 to 3-3/8"	3-3/8" to 4"
SPEED IN R. P. M.		139.5	114.8	90.8	74.3	58.5	47.8
OPERATIONS		X	X	X	X	X	X
(1) Turret Back, Turn & Up		0.20	0.20	0.20	0.20	0.20	0.20
(2) DRILL or REAM	LENGTH OF "A"						
"a" Feed=.01000	1/2"	0.59	0.68	0.81	0.94	1.15	1.36
	3/4"	0.79	0.92	1.11	1.31	1.58	1.54
	1"	0.99	1.16	1.41	1.66	2.05	2.92
	1-1/4"	1.18	1.40	1.72	2.05	2.47	3.10
	1-1/2"	1.38	1.64	2.02	2.41	2.91	3.67
	1-3/4"	1.57	1.88	2.32	2.78	3.34	4.25
	2"	1.77	2.12	2.63	3.15	3.78	4.83
	2-1/4"	1.96	2.39	2.93	3.52	4.22	5.40
	2-1/2"	2.16	2.60	3.23	3.89	4.65	5.98
	2-3/4"	2.36	2.84	3.53	4.26	5.09	6.36
	3"	2.56	3.08	3.83	4.63	5.53	7.14
"b" Feed=.01818	1/2"	0.42	0.47	0.54	0.62	0.72	0.84
	3/4"	0.53	0.60	0.71	0.82	0.98	1.16
	1"	0.63	0.73	0.87	1.02	1.24	1.47
	1-1/4"	0.74	0.86	1.04	1.22	1.49	1.79
	1-1/2"	0.85	0.99	1.20	1.42	1.75	2.10
	1-3/4"	0.95	1.12	1.37	1.63	2.00	2.42
	2"	1.06	1.25	1.53	1.83	2.26	2.73
	2-1/4"	1.17	1.38	1.70	2.03	2.51	3.05
X=TIME WORK SHOULD TAKE	2-1/2"	1.28	1.51	1.86	2.23	2.77	3.36
	2-3/4"	1.76	1.64	2.03	2.43	3.03	3.68
	3"	1.49	1.77	[illegible]	2.63	3.29	3.99
"c" Feed=.04347	1/2"	0.29	0.31	0.34	0.37	0.42	0.47
	3/4"	0.34	0.37	0.41	0.46	0.53	0.60
	1"	0.38	0.42	0.48	0.54	0.64	0.73
	1-1/4"	0.43	0.48	0.55	0.63	0.75	0.86
	1-1/2"	0.48	0.53	0.62	0.71	0.86	1.00
	1-3/4"	0.52	0.59	0.69	0.80	0.96	1.13
	2"	0.56	0.64	0.76	0.88	1.07	1.27
	2-1/4"	0.61	0.70	0.83	0.97	1.18	1.40
	2-1/2"	0.65	0.75	0.90	1.05	1.29	1.53
	2-3/4"	0.70	0.81	0.97	1.14	1.40	1.66
	3"	0.75	0.87	1.04	1.23	1.51	1.79

SPEEDS

SYM	R.P.M.	SYM	R.P.M.
1BS	47.8	2BF	90.8
1BF	56.5	3BS	114.8
2BS	74.3	3BF	139.5

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FIG. III.—RATE TABLE

rate tables. The method that should be employed is to make up first a base rate table for the simplest form of operation, whether the class is that of a line of product simply varying in size or the class which covers the operations to be performed on a certain type of machine, and then supplementary rate tables for the additional operations required for the more complicated forms. This plan makes it possible to tabulate all necessary data in a much more condensed form and according to a simpler arrangement than if separate tables are compiled

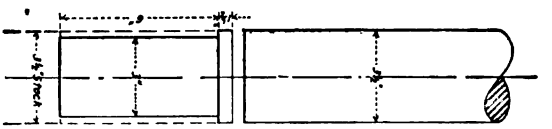


FIG. 112.—STANDARD STEEL PIN

for each particular form, as only two varying dimensions have to be cared for on each table. A table for each varying form and type of product would necessitate repeating the data for the simplest form in combination with other data on each rate table, which would be difficult to do and result in a complicated arrangement for most of the tables. With a base table and supplementary tables for additional operations the necessary data for any form of product can be easily gathered and a further advantage is realized in that any necessary changes in the tables can be made comparatively easily and new variation tables may be readily added to the records at any time.

In the examples given of the method of setting rates from rate tables, special mention was made that preparation-time allowances were disregarded or that the rate arrived at was the task time. For establishing rates of pay a certain amount of time has to be added to the task time for preparation, such as changing jobs, setting up machines, etc., in order to have a fair basis upon which to figure recompense. Preparation time varies greatly in different establishments, so careful time studies should invariably be taken to determine the proper time to allow for preparation. In a well standardized shop, to use a common expression for a shop under able management, the preparation time would probably be but a half or even a third of that necessary for a shop not standardized. It is quite obvious, then, that it is of the greatest import to standardize and bring under control the efforts of the managerial group before standards can be set for the workmen with any reasonable

expectation that they can be maintained or prove of much value.

One other hackneyed subject that will bear repetition is the necessity for the standardization of speeds and feeds for machine tools before effective use can be made of time-study data. Satisfactory rate tables can only be effectively compiled and made of value when the speeds and feeds of all machine tools to which the tables in any way refer are standardized. That means that every machine in the establishment should be brought to standard, for the time-study work will affect every piece of equipment—if not immediately, then as soon as any progress is made.

APPENDIX V

INVESTIGATIONS OF MOLDING PROCESSES

APPENDIX V

INVESTIGATIONS OF MOLDING PROCESSES

THE taking of time studies on machine operations—in the machine shop, for example—which has now evolved into a pretty well standardized procedure along approved and proven lines, has been developed only through years of painstaking investigations of the individual operations involved, their classification and standardization and effective combinations. The same may be said to some extent of the approved methods of arriving at effective rates for performing other work which at first might appear to involve too much handling time and to be governed by too many conditions seemingly so variable in nature as to offer little encouragement of establishing reliable measures of time.

The success with which accurate rates are predetermined, even now, for a pretty various assortment of work in different industrial activities proves the soundness of the principles upon which time study is founded * and indicates that there is not a line of industrial work which involves repetition of operations in more or less regular cycles which, if comprehensively investigated, cannot be quite thoroughly rated as to time work should take. The chief difficulty in the way of rapid progress in predetermining rates lies in the lack of the necessary time-study data, the need for which can only be met by accumulating information derived from comprehensive investigations in all lines of industry as to approved methods of procedure in performing necessary operations, unit times for elementary operations, sequences of elements for fundamental operations and establishing times for all acts that can be standardized.

An investigation of this character is well illustrated in a search for a time-rate to set on preparing a metal flask, with drag and cope, for pouring a steel casting—the molding to be by hand, in dry sand—conducted at the Watertown Arsenal, Boston, Mass.

A careful time study of the complete task of molding was entailed and the condensed summary of the data secured will

* See Chapter I.

clearly outline the procedure adopted and show the thoroughness with which such an investigation should be conducted. The task involved four major fundamental operations: 1. Setting and ramming the drag; 2. Setting and ramming the cope; 3. Finishing the drag; 4. Finishing the cope—besides the necessary handling of the completed mold and moving it to its proper place on the foundry floor. Conveniently tabulated, the data secured was as follows:

TIME-STUDY INVESTIGATION
OF
SYEEL MOLDING IN METAL FLASKS
DRAG AND COPE

(A) SET AND RAM DRAG

Operation No.			*Minutes*
1	Set mold board (includes "level off for mold board").		
	Level off	1.20	
	Set mold board	0.80	
			2.00
2	Set drag pattern on mold board		2.50
3	Hoist and land drag on mold board		
	Call crane	.88	
	Fasten 4 hooks to drag	.15	
	Make taut	.09	
	Hoist drag	.15	
	Travel	.22	
	Lower on board	.36	
	Remove hooks	.09	
			1.94
4	Hoist and remove bottom plate.		
	Loosen and remove 3⅝" bolts (helper loosens 3)	0.90	
	Hoist and remove plate	.75	
			1.65
5	Set and tighten 6-in. clamps. Time per clamp = 0.30 min. (includes setting and wedging up). 6 clamps per drag		1.80
6	Set gates for bottom pour (combines with operation No. 9 and time includes bottom pour).		
7	Set rods. It varies from 1.00 min. on the recoil cylinder to 8.25 min. on the sheave bracket. Ordinarily 3.00 min. would cover most cases.		
8	Time to fill drag and ram up.		

*Sand Required for Drag**

Amount of sand required = (cubic ft. of drag—cubic ft. of pattern) x 2.

Amount of facing required = cubic ft. of pattern x 3.25.

Amount of backing required = cubic ft. of sand required—cubic ft. of facing.

NOTE: Cubic ft. of pattern can be figured from estimated weight of casting $= \frac{W}{0.283 \times 1728}$ plus risers, if there are any.

* A facing shovelful is a heaping shovel, and is handed to moulder by helper, and placed where required. A backing shovelful is an amount that can be put on the shovel in the ordinary manner of shoveling and is shoveled in by helper.

Facing shovelful = 0.28 cub. ft.
Backing shovelful = 0.23 cub. ft.

Operation No.	*Time to Fill Drag*		*Minutes*
	Time to fill in one cubic ft. of facing	0.475	
	Time to fill in one cubic ft. of backing	0.190	
	Time to Ram Drag		
	Time to peen ram one cubic ft.	0.10	
	Time to butt ram (air) one cubic ft.	0.14	
9	Cut out bottom, pour gate, nail, silica wash and cover with core plate. Combines with operation No. 6		
	Set sprue	.35	
	Set connecting gate	.30	
	Clear away for gate	1.20	
	Cut gate	1.50	
	Set 6 rods ¼″ x 6″	.70	
	Smooth up	2.10	
	Draw sprue	.20	
	Set nails	.82	
	Silica wash	.57	
	Set and adjust core plates	1.05	
	Shovel in facing sand		
	Tuck in facing sand	.28	
	Ram facing sand	.45	
	Set iron plate over	.60	
			10.12*
10	Strike off.		
	Strike off with shovel is done by helper (no time allowed)	per sq. ft.	.0.75
	Man and helper strike off with strike*		
	Man and helper level off with strike		
11	Hoist and land bottom plate.		
	Call crane	.88	
	Hoist and land bottom plate	.75	
	Adjust bottom plate to match hole. (Pound with dolly bar)	.48	
	Bolt bottom plate to drag (6 bolts). Man puts in 3 bolts while helper puts in 3	3.00	
	Wedge between plate and drag	.80	
			5.91
12	Hoist and roll drag over.		
	Call crane†	.....	
	Fasten 2 hooks	.15	
	Make taut	.12	
	Hoist and roll over	.81	
	Hoist and set on bed	.21	
	Remove hooks	.09	
			1.38
13	Remove clamps and mold board.*		
	Knock loose 6 clamps	0.45	
	Remove board	0.30	
			0.75
14	Make joint preparatory to setting cope.		
	For ordinary drag, 0.30 min. per sq. ft. of net surface, up to 1.20 min. per sq. ft. for a difficult one. Per sq. ft.		0.30

NOTE: Size of drag about 3″ wide by 3″ deep by 7″ long.

* This time is practically the same for all sizes of drags.

* Strike is a metal-bound wooden strip about 1″ x 3″ x 96″, operated by man and helper. Level with strike operated in the same manner, except that a block is used against drag by each man, as a distance piece.

† This operation is done immediately following the above operation and crane is already at the job.

* Clamps are knocked loose by molder and board is removed by molder and helper. Helper removes board and clamps to one side.

Operation No.	(*B*) Set and Ram Cope		*Minutes*
15	Set cope pattern		1.50
16	Hoist and land cope on drag		
	Call crane	.88	
	Fasten hooks	.15	
	Make taut	.08	
	Hoist cope	.36	
	Travel 50 ft.	.75	
	Put in flask pins	.60	
	Lower on to drag	.50	
	Remove hooks	.09	
			3.21
17	Set risers and sprue. (Time is figured with operations 23 and 24.)		

Risers

Size	3″ Sprue	6″	8″	10″	12″
Setting Risers.					
Get risers 10 ft. away, per riser	0.09	0.09	0.09	0.09	0.09
Set riser	....	.15	.15	.15	.15
Set sprue	.15	....	....	....	....
Total	.024	0.24	0.24	.024	0.24
Draw risers.					
Wet surface	.09	.09	.09	.09	.09
Smooth up around riser with trowel.	.30	.30	.30	.30	.30
Rap	.12	.12	.15	.18	.21
Draw sprue	.30	....	....	....	....
Draw riser	....	.30	.35	.40	.45
Ream and smooth up	.50	.60	.69	.77	.85
Total	1.31	1.41	1.58	1.74	1.90
File and Ream.					
Fill in facing (riser hole)	....	0.22	0.22	0.22	0.22
Spread	....	....	....	....	....
Peen Ram	....	.23	.26	.29	.32
Butt ram	....	.29	.33	.37	.41
Silica wash	0.33	.40	.45	.50	.55
Total	0.33	1.15	1.26	1.38	1.50
Reamer on Joint Side.					
Ream out riser	....	1.25	1.29	1.40	2.00
Set nails	....	0.65	0.90	1.18	1.40
Total	....	1.90	2.19	2.58	3.40
Grand total	1.88	4.70	5.27	5.94	7.04

18 Fill cope.

Sand Required for Cope (see note)

Amount of sand required = cubic ft. of cope, cubic ft. of pattern (risers, if there are any) x 2.

Amount of facing required = cubic ft. of pattern risers (surface of cope x 1½″ depth) x 2.25.

Amount of backing required = cubic ft. of sand required—cubic ft. of facing.

Time to fill in one cubic ft. of facing	0.475
Time to fill in one cubic ft. of backing	0.250

Note: If cope were properly ribbed this operation would be unnecessary.
* Cubic feet.

Operation No.		Minutes
19	Set rods (See operation 7).	
20	Set gaggers.†	

Length of gaggers in inches.....	10	12	15	18	20	24
Time in minutes to set one gagger	0.084	0.100	0.125	0.150	0.167	0.200
Number of gaggers per sq. ft....	8.5	8.1	7.4	6.9	6.7	6.5

Operation No.			Minutes
21	Ram cope.		
	Time to peen ram one cubic ft....................	0.20	
	Time to butt ram (air) one cubic ft................	0.30	
22	Strike off cope with trowel. Per sq. ft................		0.15
23	Draw risers and sprues (See operation 17).		
24	Fill in and ram riser holes (See operation 17).		
25	Set and clamp plate to support in rolling over.		
26	Hoist and roll cope over.		
	Call crane....................................	0.88	
	Fasten 4 hooks (man, 2; helper, 2)................	.15	
	Make taut.....................................	.09	
	Draw..	.15	
	Hoist...	.15	
	Fasten 3 hooks from other trolley................	.21	
	Hoist second trolley, lower first.................	.42	
	Swing cope 180°................................	.09	
	Hook on 4 hooks (first trolley)....................	.36	
	Hoist level....................................	.45	
	Lower to bed...................................	1.20	
	Remove hooks..................................	.21	
		——	4.36

(C) Finish Drag

27	Finish joint before drawing pattern. For the ordinary drag, time equals 0.17 min. per sq. ft. net of surface of drag. In some cases it might go higher. Per sq. ft............................	0.17	
28	Draw pattern. From present data, time equals no. cubic ft. in pattern x 0.85 min.		
29	Patch mold after pattern is drawn. Time equals no. cubic ft. in pattern x 1.70 min.		
30	Cut gates.*		
	Cut gate 3″ x 3″ x 6″ long......................	.80	
	Smooth up.....................................	1.70	
	Draw sprue....................................	.20	
	Ream..	1.28	
	Set 15 nails....................................	.82	
	Lift out loose sand.............................	1.50	
	Air blow out..................................	.50	
	Smooth up.....................................	.60	
		——	7.40
31	Set nails (3″ nails). Nails per sq. ft., 42 up to 50. Set and push nail in, 0.05 min. per nail, up to 0.075 min. per nail.		
32	Cut brackets.†		

	3/8″ x 1″ x 2½″ long	3/8″ x 1½″ x 6″ long *Use Templet*
Lay off for bracket. Mark per bracket....................	0.12 min.	0.12 min.
Cut bracket....................	.30	2.00
Smooth up....................	.30	1.20
Lift out loose sand. Per bracket	.25	.50
Air blow out sand. Per bracket.	.05	.05
	1.02	3.87

† Length or size of gagger equals depth of cope. Square feet of gaggers to set equals area of the cope minus area of the pattern surface in the cope plus the area of the risers.
* All gates for steel molding are about the same.
† Brackets are slits cut in the mold, where two parts come together, and are for relieving the strain when casting is cooling.

Operation No.			*Minutes*
33	Silica wash. Time per sq. ft. of area washed............ Area washed—exposed surface of flask, plus exposed surface of pattern, plus exposed surface of risers.		0.25
	(*D*) Finish Cope		
34	Finish cope before drawing pattern. For ordinary cope, this time equals 0.30 min. per sq. ft. of net surface. Per sq. ft....................................		0.30
35	Draw pattern. From present data, time equals no. cubic ft. in pattern times 0.85 min.		
36	Patch after drawing pattern. Time = no. cubic ft. in pattern times 1.70 min.		
37	Ream risers. (See operation 17.)		
38	Smooth over nails. (20 or more at a time) 0.0175 per nail. Setting nails and smoothing, allowing 42 nails per sq. ft. at 0.05 min. per nail for setting, and 0.175 min. per nail for smoothing = 2.835 min. per sq. ft.		
39	Cut brackets. (See operation 2.)		
40	Silica wash. Time = .25 min. per sq. ft. of area washed. See note under Operation 33. Per sq. ft..........		0.25
41	Hoist and rest cope on drag.		
	Call crane....................................	0.88	
	Fasten 2 hooks...............................	.15	
	Make taut.....................................	.06	
	Hoist cope.....................................	.15	
	Put blocks on drag............................	.60	
	Lower onto blocks on drag......................	.36	
	Remove hooks..................................	.09	
		——	2.29
42	Hoist cope and drag and put to one side.		
	Fasten 2 hooks on drag.........................	0.15	
	Make taut.....................................	.06	
	Hoist drag and cope............................	.33	
	Travel 20 ft..................................	.21	
	Lower to floor.................................	.21	
	Remove hooks..................................	.09	
		——	1.05

An allowance for fatigue of 25% should be added.

The observations on some of the numbered operations entailed the development of methods to arrive at conclusions as to time requirements by simple calculations if the results of the investigation were to be made generally applicable—for example, in the case of Operation No. 8, "Time to fill drag and ram up"—and it is of considerable interest to compare the results secured through the use of the more or less empirical formula method and those arrived at through carefully conducted time studies. The practical value of such time-study investigations depends in no small measure upon the accuracy of any empirically derived formulas. A comparison of conclusions on the time required to fill and ram various sizes of drags, accommodating different sizes of patterns, arrived at by the formulas derived and by comprehensive time studies, follows, from which it will be seen that the results secured by the two methods are, for all practical purposes, the same.

COMPARISON OF CALCULATED CONCLUSIONS AND TIME STUDIES

For Drag

Size of drag in inches, 60 x 26 x 14.

Cubic ft. of drag	= 12.70		
Cubic ft. of pattern	= 1.58		
Total amount of sand required	= 11.12 x 2 = 22.24		
Amount of facing required	=	5.13 x 0.475	= 2.44
Amount of backing required	=	17.11 x 0.19	= 3.25
Peen ram	=	22.24 x 0.10	= 2.22
Butt ram (air)	=	22.24 x 0.14	= 3.11
			11.02
	25%		2.75
	By time study		13.90

Size of drag in inches, 48 x 48 x 32.

Cubic ft. of drag	= 41.72		
Cubic ft. of pattern	= 5.00		
Total amount of sand required	= 36.72 x 2 = 73.44		
Amount of facing required	=	16.25 x 0.475	= 7.72
Amount of backing required	=	57.19 x 0.19	= 10.87
Peen ram	=	73.44 x 0.10	= 7.34
Butt ram (air)	=	73.44 x 0.14	= 10.28
			36.21
	25%		9.05
			45.26
	By time study		47.46

Size of drag in inches, 72 x 48 x 24.

Cubic ft. of drag	= 48.		
Cubic ft. of pattern	= 5.12		
Total amount of sand required	= 42.88 x 2 = 85.76		
Amount of facing required	=	16.65 x 0.475	= 7.90
Amount of backing required	=	69.11 x 0.19	= 13.15
Peen ram	=	85.76 x 0.10	= 8.57
Butt ram (air)	=	85.76 x 0.14	= 12.00
			41.62
	25%		10.41
			52.03
	By time study		60.62

Size of drag in inches, 60 x 68 x 16.

Cubic ft. of drag	= 37.70		
Cubic ft. of pattern	= 3.25		
Total amount of sand required	= 34.45 x 2 = 68.90		
Amount of facing required	=	10.56 x 0.475	= 5.00
Amount of backing required	=	58.34 x 0.19	= 11.07
Peen ram	=	68.90 x 0.10	= 6 89
Butt ram (air)	=	68.90 x 0.14	= 9.65
			32.61
	25%		8.15
			40.76
	By time study		43.77

A time-study investigation of this nature not only furnishes valuable data for computing reasonable rates for work and setting time allowances for tasks of similar specific character, but may be amplified and analyzed with a view of developing tabulated or chartered time-study records in forms to simplify and expedite rate setting materially. At the Watertown Arsenal this was not done, but the more restricted investigation produced much valuable information now available for further developments in the standardization of foundry practice and rating methods.

APPENDIX VI

RATING FOR DROP-FORGING OPERATIONS

APPENDIX VI

RATING FOR DROP-FORGING OPERATIONS

TIME-STUDY investigation carried through to a comparatively high degree of development from which an unusually convenient and effective system for checking times was made up from the data secured. This data was arranged in the form of curves and is well typified in the procedure of determining the correctness of time-study observations for drop-forging work. With the curves as an aid it is only necessary to take a few observations to determine the sequence of the elementary operations and any features peculiar to the operation.

From these observations an instruction card can be made up and the time for each standard elementary motion can be taken from the curves. With such a guide accurate rates can be set. During the development of the system time studies were taken of every elementary operation in any way connected with the work under observation. The data secured was analyzed, summarized, grouped, arranged and systematically tabulated. Finally, the nature of the work had been standardized as to character, procedure, weight, material used, and the equipment diagramed as to location, etc. (See typical plan, Fig. 113.)

This study shows that with a thoroughly standardized equipment exhaustive time studies could be taken from which tables or curves may be worke up that wo ld allow the predetermining of a rate from the drawing for any drop forging.

A description of the method used to arrive at the task time for a drop-forging job with the aid of these curves and an illustration of an instruction card for a specific job to show the ease with which it is compiled will serve admirably to bring out the value of such time-study work, not only where these curves have been used, but to industry in general. The example should be particularly illuminating, for the character of the work is quite different from the ordinary run of machine-shop

work with which time-study work is so commonly associated in the public mind.

The procedure in conducting any work so well standardized as must be that of a drop-forge shop employing a system of rating work from time-study data must follow a definite set of rules governing executive actions quite as much as those of the

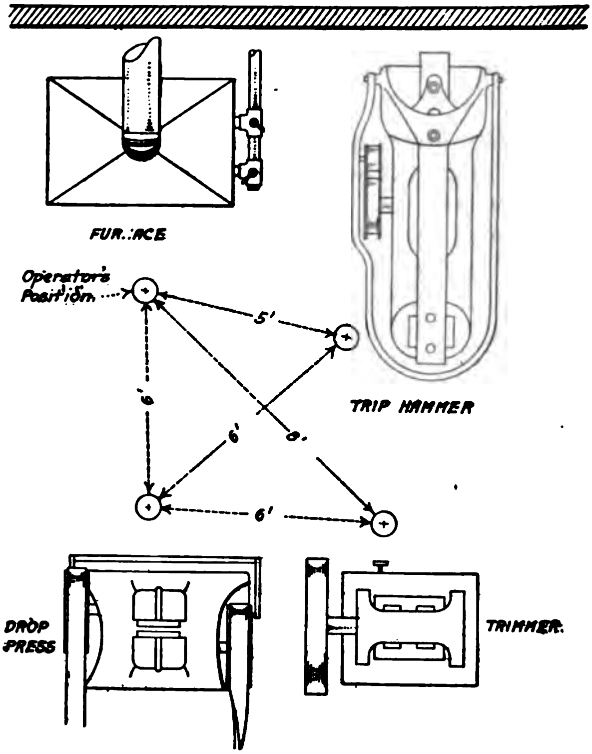


FIG. 113.—TYPICAL PLAN OF DROP-FORGING DEPARTMENT

workmen. Managerial and productive departments must co-operate. This is well exemplified in the clear-cut instructions, which follow, for the use of the time-study curves.

Instructions for the Use of Time-study Data Curves and Notes on Forging Procedure

1. The first step is to determine the dimensions of the bars necessary to produce the desired piece. Also the length of bar

and number of bars operator can carry conveniently at one time. Use Curve "*C*" for walking time.

2. Then figure the necessary number of cubic inches to be heated on end of bar and from that obtain the proper heating time, Curve "*B*."

NOTE: *The above items are known as preparation time.*

3. After first bars put in furnace are heated pick one bar out of furnace and carry to trip hammer for drawing or to drop for forming, whichever is necessary, using Curve "*C*" for walking allowance after distance has been ascertained.

4. If bar is taken to trimmer for drawing allow 0.03 min. for placing, adjusting, tripping and allowing hammer to attain full motion. When trip hammer has attained full motion, count number of blows necessary to perform drawing operation and make allowances as per Curve "*D*," considering weight of hammer.

5. Should it be necessary to re-insert bar in furnace after drawings make allowance using Curve "*C*" for distance traveled.

6. If bar is taken to drop allow 0.03 min. for placing on die and tripping where dropping is done immediately after forming and on the same machine.

7. Forming and dropping time is determined by the number of blows necessary for each operation, taking into consideration the type of drop necessary; *i. e.*, heavy, light or steam, using Curves "*E*" for this purpose.

8. If trimming is necessary, walking allowance from drop to trimmer must be made—determine number of feet and use Curve "*C*."

9. For placing under trimmer, adjusting and tripping, allow 0.02 min.

10. For trimming allow 0.015 min.

11. For clearing trim allow from 0.02 min. to 0.05 min., depending on size.

12. If necessary to brush off scale with wire brush after trimming, allow ———.

13. Move bar, place under cut-off and trip—allow 0.03 min.

14. Cut-off—allow 0.015 min.

15. After cut-off return bar to fire, make allowance as per Curve "*C*" for distance traveled.

16. Figure out the number of pieces that can be obtained from the bars inserted in the furnace. Then multiply the time per piece or cycle of all elementary operations described above by number of pieces obtainable. This gives the total time for all

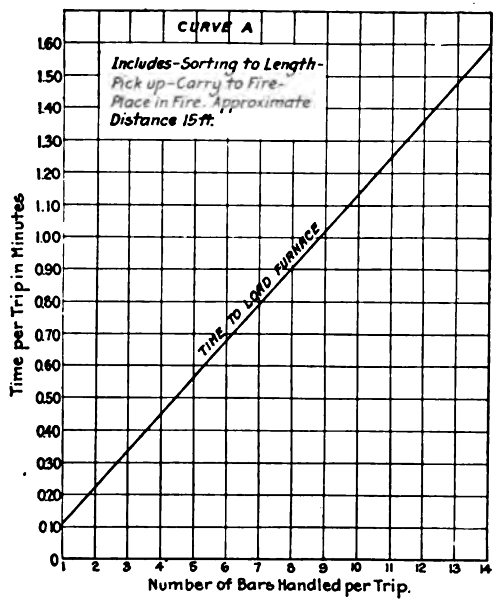


FIG. 114.—TIME-STUDY-DATA CURVE FOR LOADING FURNACE

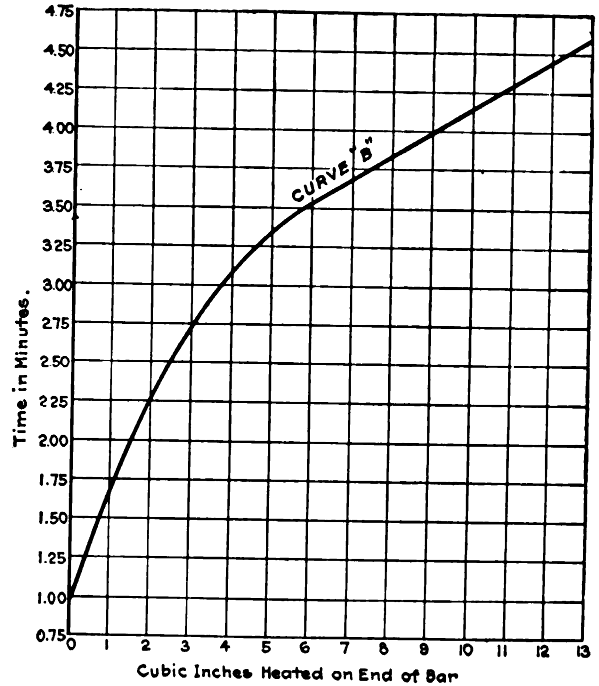


FIG. 115.—TIME-STUDY-DATA CURVE FOR HEATING BARS

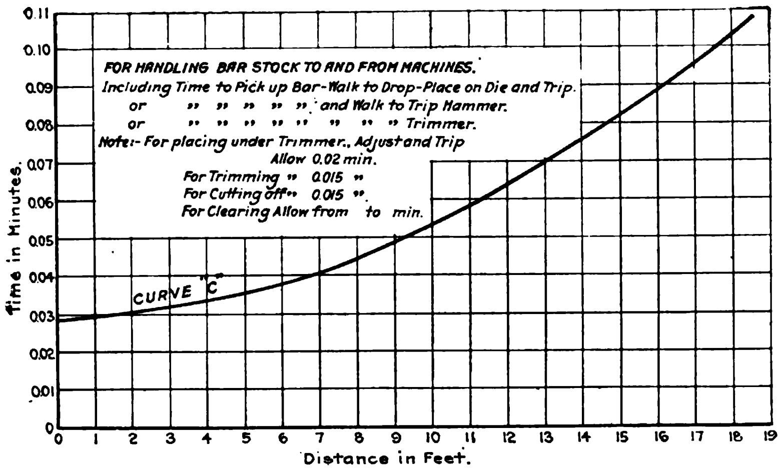


FIG. 116.—TIME-STUDY-DATA CURVE FOR HANDLING STOCK

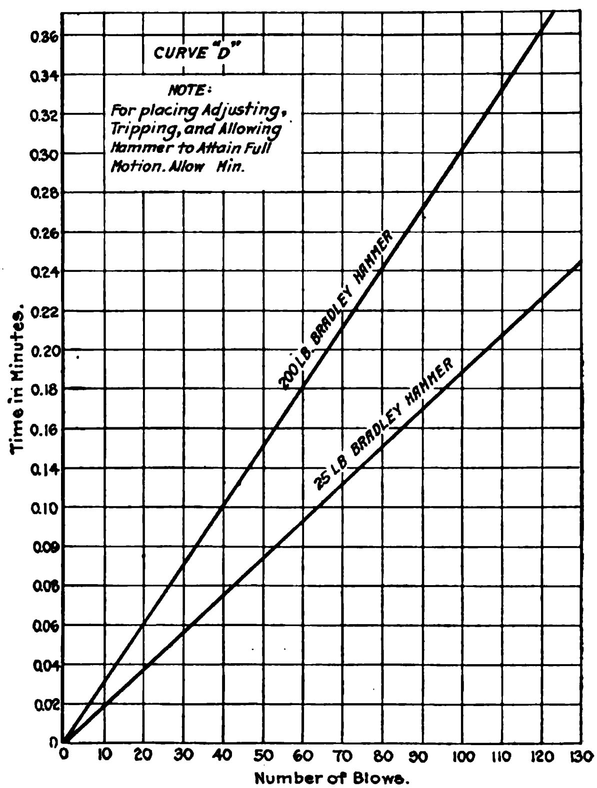


FIG. 117.—TIME-STUDY-DATA CURVE FOR TRIP HAMMER

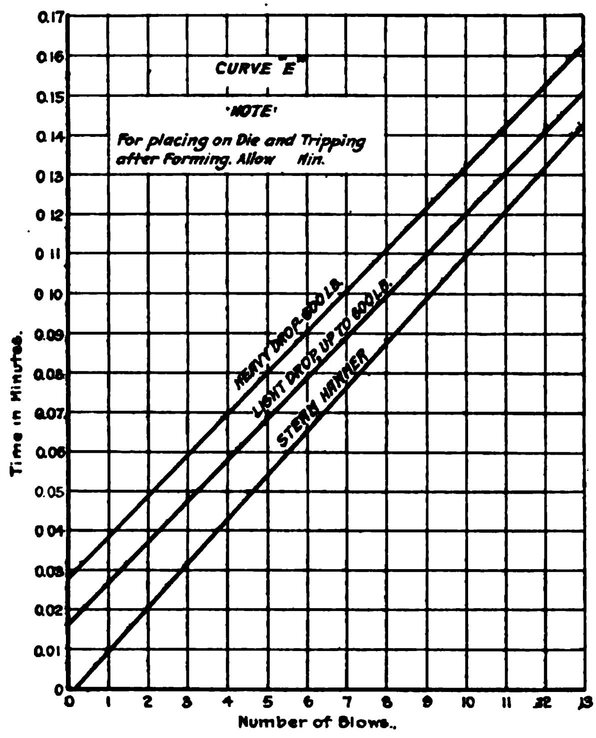


FIG. 118.—TIME-STUDY-DATA CURVE FOR FORMING

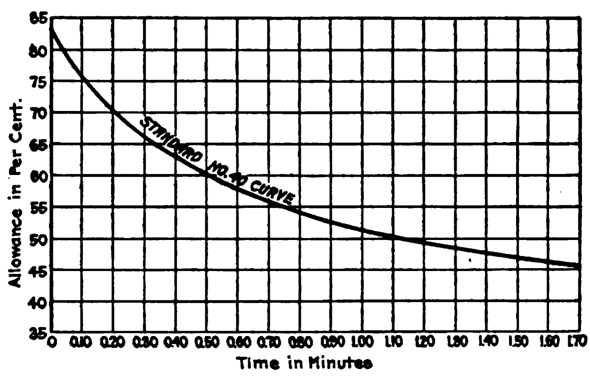


FIG. 119.—DROP-FORING ALLOWANCE CURVE

10 Sheets-Sheet 4

DROP FORGING
DATA

Illustrative Instruction Card to Assist in Estimating.

Elementary Operations.	Prep. Time	Curve Time	Curve Used
1. Load Furnace with 6 Bars 3.5% Nickel Steel 1" x 86" 3 Trips	.23		A
2. Wait for 1st two bars to heat (# of cu.in on end of bar to heat)	1.50		B
3. Carry bar to Bradley Trip Hammer 6 Ft.		.038	C
4. Place and Adjust, Trip and Allow Hammer to Attain Full Motion		.03	D
5. DRAW (Ave. No. of blows Struck 33) 200 lb. Hammer		.10	D
6. Re-insert Bar in Fire 6 Ft.		.038	C
7. Carry Bar from Furnace to Dies 4 Ft. & Trip		.034	C
8. FORM 2 Blows 1000 lb. Drop		.05	E
9. Place piece on Die and Trip after Forming		.03	E
10. DROP 5 Blows 1000 lb. Drop		.08	E
11. Carry Bar to Trimmer 7 Ft.		.041	C
12. Place Bar under Trimmer, Adjust and Trip		.02	C
13. Trim		.015	C
14. Clear Trim		.05	C
15. Brush off Scale with Brush (Wire)		.07	
16. Carry Bar back to Dies 7 Ft.		.041	C
17. Knock off Scale with poker, if necessary .07 x 1/4		.018	
18. DROP 3 Blows		.06	E
19. CARRY Bar to Trimmer 7 Ft.		.041	C
20. Place under Trimmer, Adjust and Trip		.02	C
21. TRIM		.015	C
22. Clear Trim		.05	C
23. Move Bar and place under Cut-Off Trip		.03	C
24. CUT-OFF		.015	C
25. Return Bar to Fire 8 Ft.		.044	C
26. Repeat elements 3 to 25- 59 times		54.87	
	1.73	55.80	

TOTAL SELECTED TIME	55.80
____ MACHINE TIME, POWER FEED at ____	
____ MACHINE TIME, HAND FEED at ____	
55.80 HANDLING TIME (# — CURVE) at 52%	29.02
WORKING CYCLE	84.82
1.73 PREPARATION TIME, PLUS 75 % =	3.16
	86.98
ALLOWANCE FOR WASHING & OILING at 7½ %	6.50
TIME FOR 60 PIECES	93.48
TIME FOR ONE PIECE	1.558
HOURLY PRODUCTION 38.5	
BASE RATE $.59 RATE PER HUNDRED $1.69	
MAN OPERATES — MACHINES ON OPERATION NO —	

INSURANCE No.

DRAWN BY DATE 4-30-17 | CHECKED BY DATE | REVISED BY DATE

FIG. 120.—DROP-FORGING INSTRUCTION CARD

the pieces, after allowance for loading furnace and heat wait have been added.

17. To determine hourly production: Derive the per cent. of allowance from curve drawn up especially for estimating purposes (equivalent to regular No. 40 Curve), basing reading on the time per cycle. When this is obtained, add it to the total selected. This gives the working cycle. To the preparation time add 25 per cent. allowance. To this a flat shop allowance of 7½ per cent. is added for washing up, oiling, heating furnace and warming dies. This gives the time per piece with all allowances added. To arrive at the hourly production, divide 60 by the time per piece.

Curves "*C*," "*D*" and "*E*," referred to in the foregoing instructions and illustrated in Figs. 116, 117 and 118, record in a convenient manner much valuable time-study data. The curve for handling the stock, Fig. 116, apparently disregards the question of load the operator is supposed to carry, but this is not overlooked, as the rate setter is instructed to ascertain the number of bars the worker can carry *conveniently* at one time. Curve "*D*," Fig. 117, is a double graph by which the time required to operate either a 25- or 200-lb. Bradley hammer is obtained for any number of blows. The particular hammer to use is dependent, of course, upon the character of the work and should be mentioned on the instruction card issued with the job. The curve for ascertaining the time required to form, or drop, one piece, Fig. 118, is a triple graph giving the time for blows with a heavy drop of 600 pounds, light drop of up to 600 pounds and with a steam hammer by which heavier drops may be administered. The required drop should be invariably specified on the instruction card.

Curves "*A*" and "*B*," shown in Figs 114 and 115, are also employed in determining the task time for a given job, the former giving the time required to load the furnace with the bars to be heated and the latter the time needed to heat the number of cubic inches of metal required. Finally, the curve shown in Fig. 113 and referred to in the instructions for the use of the time data curves as the regular No. 40 curve, is a delay-allowance curve similar to those discussed in Chapter V, suitable for establishing the necessary allowances for the drop-forging operations conducted at the Winchester plant.

Fig. 120 illustrates an instruction card compiled for a particular drop-forging operation and indicates, perhaps even more plainly, the convenience of the time-study-data curves as aids in rating

work. Even to the uninitiated it must be evident that it is a comparatively simple matter to take from the curves the unit times for the various operations, total them, add the necessary time allowance, also readily taken from a curve, and so determine an accurate measure of the time a set task should take. Of course, the rate setter must be familiar with the line of work he rates, but the convenience of the curves is as great to a trained man as to a novice.

APPENDIX VII

INVESTIGATING A BRASS ROLLING MILL PROCESS

APPENDIX VII

INVESTIGATING A BRASS ROLLING PROCESS

TYPICAL of approved investigations and methods followed in setting rates for operations that do not lend themselves to the refinements of time-study procedure common to the general run of machine-shop operations, is a study that was made of certain operations in a brass rolling mill. The object of the investigation was to establish a reliable measure of the work accomplished, as a basis for rate and recompense setting.

Briefly, the operation studied consisted of passing bars of brass, gilding or nickel between sets of double water-cooled rolls to bring their thickness down to specified dimensions. Both preparatory and subsequent acts to that of actually passing the bars through the rolls are entailed, which can be and were time-studied according to approved procedure for such operations, but the particular object of the investigation in question was to arrive at accurate and equitable terms in which to express the capacity of the rolls, and from which fair and equitable tallies could be arrived at for paying the men in proportion to the output realized. The details of the operation may not be the same in other rolling mills, or in the majority of mills, but the study is typical of approved procedure for the not uncommon situation that appears to defy a reasonable time study.

The heavy, break-down, rolling, previous to taking the study, had been conducted on a bonus plan of recompense, by which the men received a definite premium, or bonus, for all passes in excess of a specified number per day. The weak feature of the plan was that the bars were not always rolled from one certain thickness to another, so that the time consumed per pass would vary between wide limits; particularly would this be so if the method of recompense was extended to include the run-down, make-ready and finish passes. The scheme of measuring the work performed by the weight, or tonnage, rolled was even less practical, owing to the fact that the tonnage varied widely with the thickness of the bar, while on the

break-down, heavy tonnage could be passed in a comparatively short period of time. On the final passes, when the material had been rolled thin, it might take several hours to pass a ton of material.

As the weight of the bar remains practically constant during the rolling processes, a logical measure of the work performed by the operators would be the length gained by the bars in the various passes. This measure, logical as it is, also fails to be practical for all passes. When the bars have been rolled down to a certain thickness, the comparatively long and thin strips are coiled for facility in handling, making an accurate, measure of their length a difficult matter. However, while the bars lengthen as they are subjected to the pressure of the rolls they also widen to a certain extent, so that just as accurate measure of the work performed by the operators is set by the increase in the width of the bars. A system of rate setting based on the increase in width of the bars was decided upon, therefore, as being not only accurately established, but practical of introduction—the width of the bars being subject to fairly accurate measure, whether the material was in the form of flat bars or coiled sheets.

To collect the necessary data whereby equitable rates could be based upon the increase in width of the bars during the rolling processes, a considerable amount of information had to be collected, analyzed, correlated, and made use of. In the first place, the varieties of metal rolled, the widths of standard bars and their average weights had to be ascertained. Briefly summarized, this specific data—as it pertained to the mill where the study was made—is listed in the accompanying table, "Material Data."

MATERIAL DATA

Material..............	Brass, Gilding and Nickel.
Size of bars............	3⅜ in. to 12¼ in. wide.
Weight of bars.........	3⅜ in. wide, 42 pounds; 4⅛ in. to 5⅜ in. wide, 56 pounds; 12¼ in. wide, 168 pounds.

The handling of the bars, particularly as to the question of the weight carried by the supply trucks, was also of importance, as it is, in large measure, upon the continuity of the supply of material to the rolls that the output depends. The following trucking practice was found to be employed and to be satisfactory for the capacity of the rolls. For the break-down, sixty of the 56-pound bars constituted a truck-load; while for the run-down, make-ready and finish rollings from sixty to eighty

bars formed a load, the exact number depending upon the thickness of the bars and upon whether the thin bars, or strips, were loosely or tightly rolled. In the case of the 168-pound bars, thirteen were customarily trucked at a time, though this number was occasionally increased to sixteen per load.

The mill, or roll, speeds were already established and presumably were the best suited for the work. However, they were carefully checked and found to be for the break-down, or rough, rolling, 105 feet per minute; for the run-down, or semi-rough, rolling, 125 feet per minute; and for the make-ready and finish, the semi-finish and finish rollings, respectively, 162 feet per minute.

Standard times for use in writing up instruction cards were also established of operations performed previously and subsequently to the actual passing of the bars through the rolls. For example, 1.2 minutes is allowed for moving the supply truck in position and starting the first bar through the rolls. Such time allowance is standard for the first bar of all runs, except on the break-down, for which only 0.8 minutes is allowed —a double crew of helpers working alternately on such heavy operation. To remove and place on the receiving truck the first bar of each run, 0.030 minute is allowed, except when the material has been rolled so thin as to require the coiling mechanism being brought into use. When this becomes necessary 0.210 minute is allowed to remove the coil from the coiling block and place it on the truck. These allowances are made only for the first bar passed on each run, for the balance of the bars in any run are passed following one another in close succession, so that no starting or removing time allowances have to be provided.

Standard time allowances are also set for gaging the bars after each pass and for correcting the roll settings. On the break-down, run-down and make-ready rollings, 0.2 minute is allowed for all passes other than the final pass, for which 0.3 minute is allowed. On the final pass for finish rolling, however, the allowances are somewhat increased—being for all passes but the final one, 0.3 minute and for the final pass, 0.4 minute. Such unit times, as well as those established for moving the supply trucks to position, passing the first bar and for removing the first bar passed on each run to the receiving trucks, are arrived at by means of time studies, records of which will be presented following this general description of procedure.

On finished rolling, time is allowed for correcting the roll setting for the first bar on each pass but the last, when time is

allowed for correcting the roll setting after one or two bars have been passed.

Such, summarized, are the time allowances made for handling operations. The time consumed in the actual machine operation of rolling can be accurately arrived at by the aid of a formula, the derivation of which from recorded time-study data follows, but studies should also be made to record machine times and to check calculated data, etc. When making such studies care should be exercised to note the original casting width of the bars, for the majority of the calculations involved in arriving at the proper rate of production are based upon the casting width, rather than upon the width of the bar during any stage of the rolling down. It is also necessary to note and establish the most effective "tolerances" for each pass and how frequently the bars should be annealed, annealing being necessary on account of the surface hardening brought about by the rolling. The class of material rolled has to be taken into consideration, of course, and when possible its chemical composition should be ascertained, or, if this cannot be obtained, accurate information should be secured of the average weight of the material.

At the plant where the study under consideration was taken, the average composition of the various materials rolled and their respective weights per cubic inch are given in the accompanying table, while the widths of the castings customarily rolled are as follows:

3⅜ inches	4⅜ inches	4¾ inches	5⅜ inches
4⅛ "	4½ "	4⅞ "	12¼ "

AVERAGE COMPOSITION AND WEIGHT OF MATERIALS

Material	*Composition*	*Weight per cubic inch*
Brass	67 to 68 per cent. copper	0.3025 pound
Gilding	95 per cent. copper	0.3195 pound
Nickel (Cupro)	85 per cent. copper	0.3219 pound

The machine, or rolling, time is proportional to the thickness to which the metal is rolled, the increase in bar width resulting from the rolling, the volume of the bar remaining constant, and, of course, to the class of material and the speed of the rolls. Based on such hypothesis, studies were made to determine the proportional increase in width of bar for various reductions in thickness. A great number of such studies were made, using bar castings of various widths and of the different materials rolled at the mill, which were carefully studied, analyzed and classified until finally, by means of carefully

plotted curves establishing the trend of relationship between reduction in thickness and increase in width, accurate tables were evolved giving in convenient form the results secured, which are applicable to any rolling operation of the same class. Such a table, based on the increase in width of a 4½-inch bar when reduced in thickness, by rolling, from 1 inch to 0.025 inch, is given as "Reduction Table."

REDUCTION TABLE

Casting Thickness Inches	*Decrease in Thickness Per Cent.*	*Increase in Width Inches*	*Approximate Increase in Width Per Cent.*
1.000	0.0	0.000	0.0
.900	10.	.056	1.1
.800	20.	.113	2.5
.750	25.	.114	3.0
.700	30.	.169	3.7
.650	35.	.197	4.4
.600	40.	.225	5.0
.550	45.	.253	5.6
.500	50.	.281	6.1
.450	55.	.309	6.9
.400	60.	.338	7.4
.350	65.	.366	8.0
.300	70.	.394	8.8
.250	75.	.422	9.3
.200	80.	.450	10.0
.150	85.	.478	10.6
.100	90.	.506	11.1
.050	95.	.534	11.8
.025	97.5	.563	12.5

The convenience, for practical use, of a table based on the increase in width of a bar while being reduced in thickness by rolling is perhaps most clearly demonstrated by a record of the increase in the length of the bar taking place simultaneously. A 4⅞-inch bar, 1 inch in thickness and of 68 per cent. copper when rolled to 0.145 inch in thickness in seven passes was reduced 85½ per cent. in thickness, increased 10½ per cent. in width and was increased in length by 530 per cent. Quite obviously, a measure based on width, in such a case, is more readily made use of than one based on increase in length, particularly as the length of the bar casting is, as a rule, considerably greater than its width.

With the relationship established between the decrease in thickness and the increase in width of a bar passed through a set of double rolls, a formula for ascertaining the time required for rolling, per pass, is readily derived if the speed of the rolls is known and no slippage occurs—the speed of the pressed

bar issuing from the rolls, under such conditions, being the same as that of the rolls. Such a formula is:

$$T = \frac{W}{K \times B \times Th \times M \times 12}$$

Where,

T = Rolling time in minutes.
W = Weight of bar in pounds.
K = A constant, the weight of material per cu. in.
= 0.3025, for brass.
= 0.3195, for gilding.
= 0.3219, for cupro nickel.
B = Width of bar, after rolling, in inches.
Th = Thickness of bar, after rolling, in inches.
M = Mill speed in feet per minute.
12 = Conversion factor converting feet to inches.

Should any slippage occur between the rolls and the issuing material, it would be dependent in large measure upon the "tolerance" for the pass—that is, upon the difference in bar thickness before and after passing through the rolls. For this reason, the ductility of the metal—therefore, the frequency with which the bar should be annealed—also plays an important part in establishing the rolling time, and consequently the capacity of the rolls. Another factor is the use to which the rolled metal is to be put and the importance of its finish thickness—that is, the variation in thickness allowable for the use to which the metal is to be put. These important considerations require a knowledge of requirements to be secured only through experience. The facts must, perforce, be empirically established.

An example of this is well illustrated by the curves graphically depicting the required operations entailed in the rolling of U. S. Government military cartridge case brass and the metal employed for U. S. rim fire cartridge cases respectively and shown in Fig. 121. In the instance of the cartridge case brass, which has subsequently to be subjected to the operations of blanking, cupping, drawing, heading, etc., in the manufacture of the cartridge case, a 4⅞-inch brass bar, 1 inch in thickness, is rolled to 0.145 inch in thickness in seven passes; while to roll the 5⅜-inch gilding bar, used to make rim fire cartridge cases, from 1 inch to 0.015 inch, twelve passes are necessary—seven of which are necessary subsequently to the run-down roll. It is true that the gilding is rolled thinner than the brass, but gliding can be rolled closer than brass, as it is softer, so the real reason for the difference in the number of passes, as well as for the extra annealing required in the case of the gilding, is accounted for by the service for which the two materials are required.

The operations through which the cartridge brass has to pass entail a complete rearrangement of the metal in the head of the cartridge case, as far as the final rolling thickness and distribution of metal in the brass blank is concerned, so that

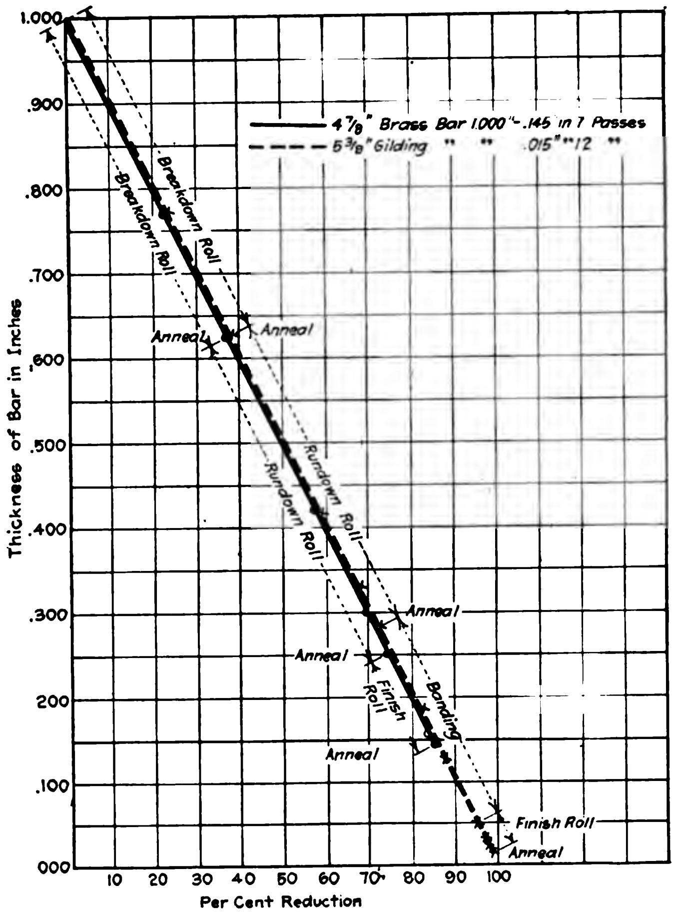
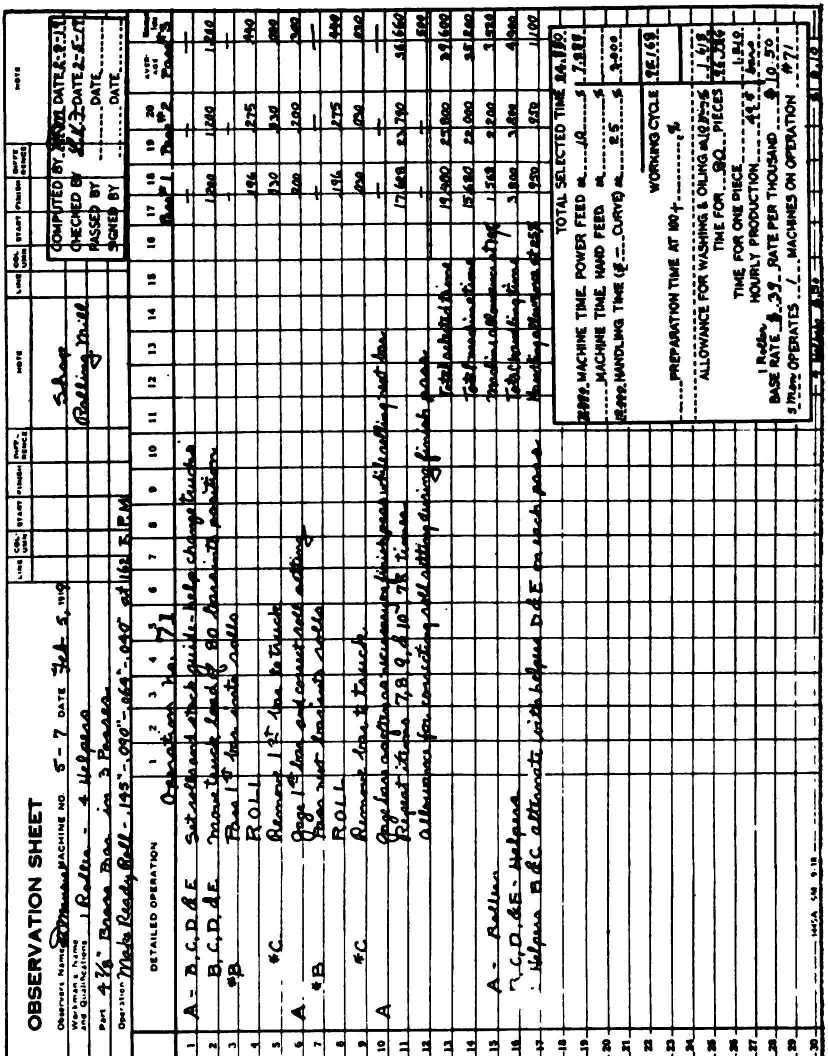


FIG. 121.—ROLLING PROCESS ON CARTRIDGE CASE METALS

a slight variation in thickness of the stock as it leaves the final pass of the rolling process is of quite secondary importance compared to the necessity of having the thickness of the gilding accurate and uniform. Rim fire cartridge case metal has to be rolled out to very nearly the same thickness as that of the head of the finished rim fire cartridge case. Furthermore, it is important that the thickness of the metal for rim fire cases be as uniform as possible, and heavy passes have the tendency



OBSERVATION SHEET

Observers Name [illegible] MACHINE NO. 5-7 DATE Feb. 5, 1919

Workman's Name and Qualifications 1 Roller - 4 Helpers

Part 4 1/8" Brass Bar in 3 Passes

Operation Make Ready Roll - .145"-.090"-.064"-.040" at 162 R.P.M.

Note: Shop Rolling Mill

COMPUTED BY [illegible] DATE 2-8-19
CHECKED BY [illegible] DATE 2-8-19
PASSED BY .... DATE ....
SIGNED BY .... DATE ....

Operation No. 71

Line		Detailed Operation	Pass 1	Pass 2	Pass 3
1	A - B, C, D & E	Set rolls and stack guide - help change trucks	—	—	—
2	B, C, D & E	Move truck load of 80 bars into position	1.240	1.240	1.240
3	#B	Pass 1st bar into rolls	—	—	—
4		ROLL	.196	.275	.440
5	#C	Remove 1st bar to truck	.030	.030	.030
6	A	Gage 1st bar and correct roll setting	.200	.200	.340
7	#B	Pass next bar into rolls	—	—	—
8		ROLL	.196	.275	.440
9	#C	Remove bar to truck	.030	.030	.030
10	A	Gage bars as often as necessary on finish pass while rolling next bar	—	—	—
11		Repeat items 7, 8, 9, & 10 - 78 times	17.628	23.790	36.660
12		Allowance for correcting roll setting during finish pass	—	—	.500
13		Total selected time	19.490	25.800	39.600
14		Total machine time	15.680	22.000	35.280
15	A - Roller	Machine allowance at 10%	1.568	2.200	3.528
16	B, C, D, & E - Helpers	Total handling time	3.800	3.800	4.900
17	Helpers B & C alternate with helpers D & E on each pass	Handling allowance at 25%	.950	.950	1.100

TOTAL SELECTED TIME 84.890
72.960 MACHINE TIME, POWER FEED at 10 % 7.296
...... MACHINE TIME, HAND FEED at ...... %
12.000 HANDLING TIME (% — CURVE) at 25 % 3.000
WORKING CYCLE 95.169
...... PREPARATION TIME AT 100 + ... %
ALLOWANCE FOR WASHING & OILING at [illegible] % 1.618
TIME FOR 80 PIECES 96.787
TIME FOR ONE PIECE 1.210
HOURLY PRODUCTION 49.6 bars
1 Roller BASE RATE $.39 RATE PER THOUSAND $10.50
5 Men OPERATES 1 MACHINES ON OPERATION #71
4 Helpers @ .30 $1.59

1445A 5M 9-18

FIG. 122.—SUMMARY OF TIME STUDY ON MAKE-READY ROLL

to leave the metal slightly thinner along the edges of the rolled sheet than at its central portion, hence the need of the light passes toward the end of the rolling processes and of the extra annealing to which the metal is subjected at the banding point.

Although the foregoing covers the main operations involved and the time allowances, etc., that are required for any rolling task undertaken in the department investigated and studied and where rates established from such investigation were put in force, individual time studies should also be made in order to check handling time allowances and record actual machine times.

An example of such a time study, well illustrating approved procedure, is furnished by that taken of the make-ready roll on a 4⅞-inch (casting width) brass bar. The rolling reduced the thickness of the bar from 0.145 inch to 0.040 inch in three passes at a roll speed of 162 feet per minute. The first two reductions were from 0.145 inch to 0.090 inch and from 0.90 inch to 0.064 inch respectively, while the final pass reduced the thickness of the bar from 0.064 inch to 0.040 inch.

A summary of the observations recorded for the individual operations performed on the three passes are entered on the observation sheet shown in Fig. 122. The method of taking the observations, their analyses and the computations involved do not differ in any way from standard time-study procedure, but it will be noted that the summarized observations contain a wealth of data. Not only are the sequence and character of the fundamental operations recorded on the observation sheet, but even the personnel performing the various acts.

The total selected, machine and handling times for the various passes are totaled and to the respective sums are added a machine-time allowance of 10 per cent. and a handling time allowance of 25 per cent., as customary. An additional allowance of ten minutes is also made for washing and oiling. The rolling time per piece and the hourly production are readily arrived at and a rate per thousand bars, calculated on the base rates of the roller and helpers, established—see computations on observation sheet, Fig. 122.

An instruction card, such as that shown in Fig. 123, is prepared, giving in detail all necessary information concerning the task, processes, sequence of operations, unit times and all time allowances. The instruction card should also give the size of the necessary crew, the task production, necessary mechanical data and full information concerning rates arranged in a convenient and explicit form, such as that illustrated.

	ROLLING MILL INSTRUCTION CARD			25 - M - 102		
OPERATION MAKE READY ROLL MATERIAL 4 7/8" BRASS BAR NO. PASSES -3						
BASE RATES-ROLLER $0.39 HELPER $0.30 MILLS NO. 5 - 7 AT 162 F.P.M.						
	OPERATION NO.					71
		Pass 1	Pass 2	Pass 3		
	TOLERANCES From .145	to .090	to .064	to .040		
	RATIO OF HAND. TO MACH. TIME	.275	.196	.142		
Item No.	DETAILED INSTRUCTIONS	Time	Time	Time		Total
1	A,B,C,D, & E Set rolls and stock guide-help change trucks	---	---	---		
2	B,C,D, & E Move truck load of 80 bars into position	1.200	1.200	1.200		
3	*B Pass 1st bar into rolls	---	---	---		
4	ROLL	.196	.275	.440		
5	*C Remove 1st bar to truck	.030	.030	.030		
6	A Gage 1st bar and correct roll setting	.200	.200	.300		
7	*B Pass next bar into rolls	---	---	---		
8	ROLL	.196	.275	.440		
9	*C Remove bar to truck	.030	.030	.030		
10	A Gage bars as often as necessary on finish pass while rolling next bar	---	---	---		
11	Repeat items 7,8,9, & 10 78 times	17.628	23.790	36.660		
	Allowance for correcting roll setting during finish pass	---	---	.500		
	Total Selected Time	19.480	25.800	39.600		84.880
	A = Roller B,C,D, & E = Helpers *Helpers B & C alternate with helpers D & E on each pass					
	Total Machine Time	15.680	22.000	35.200		72.880
	Machine Allowance at 10%	1.568	2.200	3.520		7.288
	Total Handling Time	3.800	3.800	4.400		12.000
	Handling Allowance at 25%	.950	.950	1.100		3.000
	Working Cycle					95.168
	Wash Up Allowance, 10 Min.					1.618
	Time for 80 Bars					96.786
	Time for One Bar					1.210
No. of	HOURLY PRODUCTION					49.5
1	ROLLER'S RATE PER 1000 BARS					$10.50
4	HELPER'S RATE PER 1000 BARS					$8.10
DRAWN BY A.B.M. DATE 2-6-19	CHECKED BY L.R.P. DATE 2-6-19	REVISED BY DATE				

FIG. 123.—ROLLING MILL INSTRUCTION CARD

In such manner is an equitable, effective and accurate rate arrived at for an operation that would at first thought appear to defy a reasonable time study. The principles involved differ in no way from those upon which more familiar studies are based, nor does the procedure differ in any material manner; simply a logical application of proven principles to specific conditions. Furthermore, it is obvious that after sufficient data have been compiled and conveniently tabulated for reference, new rates can be predetermined for other rolling operations without the necessity of additional time studies.

APPENDIX VIII

AN UNIQUE CONTROL OF VARIABLE TASKS

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AN UNIQUE CONTROL OF VARIABLE TASKS

IN manufacturing operations, it is frequently impractical to measure the work performed by individuals in terms of or by the production in number of pieces completed, for the work entailed may be of such a nature that the one performing it does not control the quantity of pieces produced. For example, a cycle of elements constituting a complete operation may be made up of two classes of acts, the time consumed in performing one of which is definitely fixed and constitutes the greater part of the time required for the complete operation, while the time consumed for the other, the shorter part, is more or less under the control of the one performing the work. The condition may be further complicated by the time for the fixed part differing in duration for various repetitions of the cycle of elements.

In variable tasks of such nature, it is quite obvious that time is the only common factor upon which an equitable rate of recompense for the work can be established, and that a "unit" of time may be selected as a basis which, as long as the rate of recompense per "unit" remains the same, will serve as the only variable factor in computing earnings for each complete operation. The longer part of fixed duration would be credited with a certain specific number of "units," depending upon the length of time involved, and the shorter operation under the control of the one performing the work, to a certain extent, is also credited with a certain specific number of "units." The combination of these two sets of "units" sets a definite task measure in terms of "units."

An example of an operation entailing such task conditions is well typified by that of annealing metals for the various rolling processes required to reduce the cast ingots or blocks of metal to thin sheets, for the duration of the heats is invariably long compared to the charging time. That is, the time during which the metal is retained in the furnace is long in comparison to the time required to place the metal in the furnace and for its subsequent removal. During the entire

heat, a head annealer has to care for his fires, maintain the proper furnace temperature, etc., and superintend, while his helpers, upon whom the actual work of charging the furnaces and removing the heated metal devolves, can be advantageously employed at other furnaces when not actually engaged in caring for the first furnaces.

To arrive at a measure of the work upon which to compute equitable earnings, it is obvious, only the output of the furnaces over which he has direct charge should be taken into consideration, in the case of the annealer, while, in the case of the crew of helpers, the output of all furnaces in operation should be reckoned with, as the total output is affected by the industry of the helpers. Complicating the problem still further is the fact that the duration of the various heats is not always the same. As an example of the variable duration of heats in a specific operation, the heats for annealing cartridge-case metal may be cited. The duration of the heats for the same material at different stages of the rolling processes varies between such wide limits as eighty and two hundred minutes. Time, however, is the one factor that has to be considered in all heats and is the common factor, as well, controlling the output to be credited to the furnaces over which each annealer has charge and the output of all operating furnaces cared for by the crew of helpers.

Time, then, is the logical measure for annealing processes, just as it is for any other class of work, upon which to base a recompense that is proportional to the output realized, and for convenience in computations time may be measured in any units of definite duration quite as well as in terms of hours, minutes and seconds. A "unit" may be taken as representing ten minutes, for instance, so that an annealing heat of eighty minutes would be one equivalent to eight units, or a heat of two hundred minutes, equivalent to one of twenty units. Based on such "unit" measure of time, an original and convenient control for variable tasks, such as that represented by annealing, has been developed.

In one plant, where such method of control is in force, the annealing was conducted in furnaces of the muffle type, arranged in pairs. A definite number of furnaces was in charge of one annealer, the heavy manual work of charging the muffles, etc., performed by the necessary number of helpers. The responsibility of each annealer did not extend beyond the furnaces in his charge, but the services of the helpers were made use of for all furnaces in operation at the same time, or as many

furnaces as could be properly cared for by the size of the crew engaged on the work. The duties of the helpers were to pull the pans of heated metal from the furnaces at the end of each heat and at the same time to pull the pans of metal to be annealed next into the muffles. The successive pairs of annealing pans were linked together with removable couplings, so as the pans containing the metal that had reposed in the furnaces during the preceding heat were withdrawn, pans loaded with metal to be annealed during the following heat would be drawn into the furnaces without the loss of any time.

A definite time allowance, accurately established by standard time-study procedure, was provided for drawing and charging the various furnaces, which was also expressed in "units." For instance, if the time allowed for drawing and charging a set of furnaces was placed at six minutes, each anneal would be credited with six-tenths of a unit for such operation. A definite time allowance was also made to cover the time which was required to bring the temperature of the metal charge up to the temperature required for the heat.

Recompense was based on a fixed number of "units," at a definite rate per unit. The annealer received pay for the total number of units credited to the furnaces in his charge, and only for such units, while the helpers divided the pay, at their rate, for the total number of units credited to all the furnaces in operation. Expressed in algebraic form, the earnings of the operators—the annealers and their helpers—were:

$$E = U' \times R' \text{ for annealers.}$$

$$E = \frac{U}{H} \times M \times R' \text{ for helpers.}$$

Where:

E = Earnings (Total, piece-work).
M = Piece-work hours per helper.
R' = Annealer's rate of recompense per unit.
R = Helper's rate of recompense per unit.
U' = Total units per annealer's pair of furnaces.
U = Total units for all furnaces in operation.
H = Total helpers' piece-work man hours.

The "units" credited to all the furnaces served were simply pro-rated between the helpers working, so that the smaller the number of helpers, the greater was the share received by each helper. In this way, the labor cost for an anneal of given duration remained constant so long as the unit rates remained the same—just as in the case of labor production costs on piece-work when the piece rates do not vary. The size of the crew, it is thus seen, was an important factor bearing upon the establishment of the rate per unit for the helpers.

To operate effectively a given number of muffle furnaces, a definite amount of assistance must be rendered the annealers. An annealer in charge of a certain number of furnaces, to realize a satisfactory output *must be provided* with an adequate number of helpers. The larger the furnace battery, or the greater the number of muffles in operation, the smaller need be the number of helpers required per muffle, as a rule, but an adequate crew is essential. However, as the product can only carry a certain labor cost, the aggregate of the helpers' earnings is perforce fixed to a great extent, so the helpers' rate was established on the basis of the *maximum number* of helpers *required* for given numbers of muffles operating at the same time. The maximum crews for various numbers of muffles in operation were established by approved time-study methods and the rates of recompense based upon the employment of an adequate number of helpers.

High production with a low piece cost cannot fail to be assured under this method of production control by two very potent factors. The earnings of the annealers are based on the production of the muffles in their charge, so there is a strong incentive for each annealer to conduct as many anneals as possible and eliminate all possible idle furnace time. As the duration of the various heats are established and the credit units accruing are proportioned thereto, it is to the advantage of the annealer to hasten the charging of his furnaces as much as possible. The inevitable result is that the annealers will demand a sufficient number of helpers to care for the removal of the heated charges and the introduction of fresh pans of metal to be annealed rapidly and promptly. The helpers, on the other hand, divide the units credited to all furnaces in operation, so obviously desire to keep their number at a minimum, in order for each to secure as large a share as possible of the credits. However, as the output of each muffle is of personal interest, they will not jeopardize "units" by inability to serve all operating furnaces without undue delay. The annealers demand an adequate number of helpers, while the helpers, though appreciating fully that their earnings are dependent upon their ability to serve promptly with every set of muffles in operation, can be counted upon—from motives of self-interest—to resist the employment of more helpers than necessary for the effective operation of the furnaces. Both production and their earnings are to a considerable extent in the control of the operators, so high output at low piece cost is appreciated by them quite as much as by the management.

APPENDIX IX

RATING TASKS BY TAXING WASTE

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RATING TASKS BY TAXING WASTE

ANY task entailing the formation of a considerable amount of scrap, particularly if the material worked with is comparatively inexpensive and the workers more or less irresponsible, is one in which much material is very apt to be wasted as well. Cheap though the material may be, the cost of the product becomes unduly high and the aggregate wastage not infrequently quite a substantial and, in large measure, unnecessary expense. An excellent example of such a task is that of making blue prints with the continuous, cylinder type of blue-printing machine. In such a machine, the sensitive paper is supplied continuously, the tracings or papers to be reproduced being placed on the moving blue-print paper just before it passes about the cylinder of the machine. In many establishments using such equipment it is highly probable that as much or more of the sensitive paper is wasted by not arranging the tracings compactly and economically as is productively employed. That is, the scrap paper trimmed from the washed prints is several times more than necessary and the prints cost, quite probably, twice as much as they would were the avoidable waste eliminated. Blue-print paper is not very costly, it is true, but in the many plants employing a sufficient number of blue prints to warrant the installation of one or more continuous, cylinder type blue-printing machines the annual waste in blue-print paper amounts to no inconsiderable sum.

Quite obviously, the most economical manner of conducting a blue-print department is on a task-time basis supplemented by a tax on all waste—*i. e.*, a tax on all scrap in excess of the amount justified from a practical point of view. A generous credit should be allowed for work performed, the number of prints made, against which should be debited a charge for all unnecessary scrap, in such way putting a premium on the elimination of waste. Before such a method can be introduced effectively, a quite extended time study is essential, preceded

by a thorough standardization of procedure, calibration of machines, etc.

The first requirement would be to establish an economical routing of all requisitions for the necessary materials — the tracings and the sensitive paper — for filling the requisitions for blue prints. The requisition for blue prints would go presumably to a receiving desk to be stamped, a copy filed and a requisition for the necessary tracing sent directly to the storage vault. The tracing and requisition should then pass as directly as possible to the blue-print machine, the necessary number of prints made and the tracing returned promptly to the vault. The prints should then pass to the washing and drying section without delay, be washed and dried, and then to the trimming department. The trimmed print, or prints, should then be checked and returned to the receiving desk for record, after which they should be promptly dispatched to their destination. Such, briefly, would be the usual routing of a blue print and its tracing, and the first consideration in rating a blue-print department is to ascertain whether any avoidable delays occur in such passage. Avoidable delays must be eliminated, for to justify rating the actual operations of making the blue prints it is essential to have the routine of handling prints and tracings, etc., conducted with clock-like precision, else the rating of the printing processes loses importance.

To conduct a blue-print department of any size in an effective manner, the work should be specialized and an adequate working force provided. Each blue-print machine should be in charge of a machine operator, and in addition a washer is required to wash and set to dry the output from a machine operated effectively, a trimmer to trim the prints from each busy machine and some one else to check the prints and requisitions, besides the recorder at the receiving desk. That is, for each blue-print machine kept busy enough to justify rating its operating force, four operators, each with a specific task to perform, would appear to be necessary to attain economical and speedy production, in addition to the recorder at the receiving desk, who should be capable of handling the work for several machines. Such an organization must work in harmony, co-operate, and eliminate so far as possible all idle time, else confusion and piling up of work is sure to result.

With a suitable operating force selected, instructed as to approved procedure and imbued with the spirit of co-operation, a careful calibration of the blue-print machine is necessary, for it is upon the output of the machine that the recompense

for the handling operations performed by the workers is based. The speed with which the sensitive paper is fed to the printing machine must be accurately established. This calls for a series of extended production studies, the approved procedure for taking which was described in detail in Chapter III. The speed of the paper feed is controlled on most blue-printing machines by setting a controller into one of a series of speed notches, so the object of the production studies is to record definitely

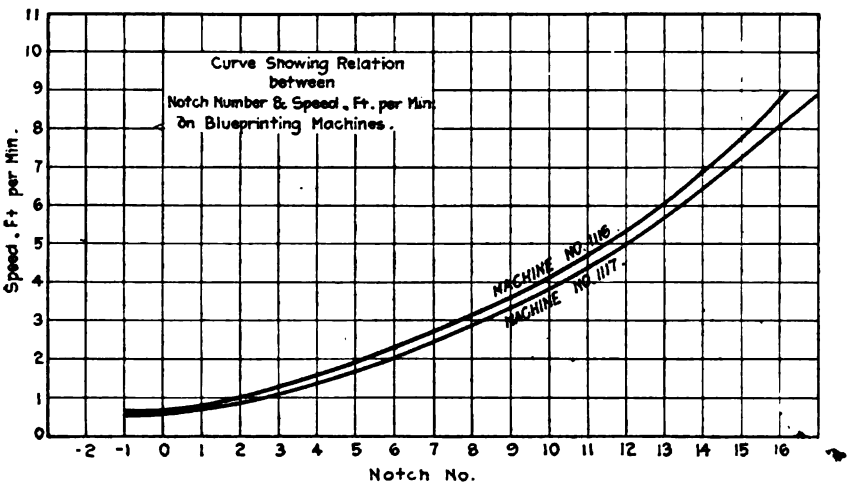

FIG. 124.—CALIBRATION OF MACHINE

the relationship between the various notch numbers and the corresponding speed of the sensitive paper about the cylinder, or drum, of the machine. From the data secured from such studies, curves may be advantageously plotted to show the relationship between the notch number and speed of paper—such as the curves shown in Fig. 124 for two machines carefully calibrated by production time studies—in order to obviate any possible errors in noting speeds or recording data. Accurate tables of paper speeds with the controller set in the various notches can then be prepared from such curves, or the curves, if laid out to suitable scale, may serve as record for the speeds.

Once the paper speeds have been accurately calibrated by notch numbers, the speeds at which various kinds of tracings, etc., are best printed—the length of exposure required—should be standardized, necessitating additional time studies, from which tables recording standard practice should be evolved.

In the average establishment making blue prints, the prints, even when standardized into specific sizes, vary more or less

in area, and it is obvious that neither the full width of the sensitive paper or its full length can be productively utilized. There must be a certain amount of scrap that is unavoidable. This proportion must be accurately ascertained by time-study procedure, making due allowance, of course, for the impracticability of obtaining the most economical arrangement of tracings, etc., on the sensitive paper while conducting productive blue printing. Both the average percentage width of paper utilized and the percentage of paper made of service should be ascertained, as both values are required to establish a basis for premiums on minimizing waste.

The amount of sensitive paper utilized in a given time can be measured with accuracy, but not so the amount of scrap, the latter being irregular and variable in shape and area, so preventing accurate surface measurement by any practical method. As a standard of sensitive paper is obviously a necessity for productive operation, however, an accurate measure of both paper utilized—*i. e.*, paper available for prints, not the total amount of sensitive paper passing about the cylinder of the machine—and the amount of scrap paper can be arrived at by weight.

The foregoing standards established by approved time-study methods, their application in the rating of blue-print production by a task and premium method with a tax placed on waste, is best demonstrated by presenting an example taken from a plant where such method of taxing waste is in force.

At the establishment in question, two blue-printing machines —employing paper 42 inches in width—are in service, the blue-printing organization consists of nine persons—two machine operators, two print washers, two print trimmers, two checkers and one recorder—and the members of the group are paid a premium based on the total production of the department. One of the machines is employed on regular straight-run work, while the other is used on work of an emergency character and work of a miscellaneous nature that necessitates different speeds of machine operation. The two machines, however, are considered as a unit in computing the task time and the time basis upon which the premium time is calculated.

Production studies and observations have established the standards that the average operating feed of the sensitive paper to the machines is 3 feet per minute; the utilized width of the sensitive paper, 80 per cent.; the weight of the paper, after washing and drying, 0.0195 pound per square foot; and the average machine time per hour, 45 minutes.

The number of pounds of usable paper per hour consumed by the two machines is then expressed by the formula:

$$\text{Weight} = S \times W \times F \times K \times M \times 2$$

Where;

S = Paper feed (speed) in feet per minute.
W = Width of blue-print paper in feet.
F = Width of paper profitably used—in per cent.
K = Weight of paper per square foot.
M = Machine time per hour in minutes,
and the final numeral of the equation denotes two machines.

By substituting the established standards for the terms of the formula, the weight of usable paper per hour from the two machines, and so chargeable to the group of nine persons constituting the personnel of the blue-printing organization, is found to be 14.8 pounds ($3 \times 3.5 \times 0.8 \times 0.0195 \times 45 \times 2 = 14.8$). Such amount is equivalent to 1 pound of paper from the two machines for the group of nine in 0.0675 hour, or to 1 pound of paper from the two machines for each person every 0.60 hour. The "time basis" for the operation is then set 66 2/3 per cent. higher, or at 1 hour.

In the foregoing computations no consideration is taken of the scrap resulting, other than limiting the weight of paper used to that available for printing purposes by virtue of the usable width factor, but in computing earnings the amount of scrap has to be taken into account, for deductions are made for wastage, or scrap in excess of an allowed amount. The permissible scrap is arrived at by extended production studies and from the data secured tables are prepared giving the "corrected weight" of paper consumed—that is, the weight of the usable paper and that of allowable scrap. Such a table is shown in Fig. 125, "Weight Table." The weights of paper listed are limiting weights, and any saving realized in consumption of paper is rewarded by a premium, depending in amount upon the saving made in scrap. In other words, wastage is subjected to a tax.

The weight of usable paper consumed in any period is obtainable by the formula previously explained and the amount of dry accumulated scrap can be accurately weighed. If, then, the weight of scrap is deducted from the "corrected weight" of paper used, as ascertained from the "Weight Table" (Fig. 125), the difference will be an accurate measure of the economy realized in the use of the blue-print paper. For instance, if 120 pounds of usable paper are consumed in a given time and the scrap resulting, washed and dried, weighs 40 pounds, a saving

has been realized. The "corrected weight" for the consumption of 120 pounds of usable paper is 162 pounds. Deducting the 40 pounds of scrap gives 122 pounds of usable paper allowed for the period. As the rate of recompense for the workers is

POUNDS USED	CORRECTED WEIGHT	POUNDS USED	CORRECTED WEIGHT	POUNDS USED	CORRECTED WEIGHT	POUNDS USED	CORRECTED WEIGHT
1.0	1.35	46.0	62.10	91.0	122.85	136.0	183.60
2.0	2.70	47.0	63.45	92.0	124.20	137.0	184.95
3.0	4.05	48.0	64.80	93.0	125.55	138.0	186.30
4.0	5.40	49.0	66.15	94.0	126.90	139.0	187.65
5.0	6.75	50.0	67.50	95.0	128.25	140.0	189.00
6.0	8.10	51.0	68.85	96.0	129.60	141.0	190.35
7.0	9.45	52.0	70.20	97.0	130.95	142.0	191.70
8.0	10.80	53.0	71.55	98.0	132.30	143.0	193.05
9.0	12.15	54.0	72.90	99.0	133.65	144.0	194.40
10.0	13.50	55.0	74.25	100.0	135.00	145.0	195.75
11.0	14.85	56.0	75.60	101.0	136.35	146.0	197.10
12.0	16.20	57.0	76.95	102.0	137.70	147.0	198.45
13.0	17.55	58.0	78.30	103.0	139.05	148.0	199.80
14.0	18.90	59.0	79.65	104.0	140.40	149.0	201.15
15.0	20.25	60.0	81.00	105.0	141.75	150.0	202.50
16.0	21.60	61.0	82.35	106.0	143.10	151.0	203.85
17.0	22.95	62.0	83.70	107.0	144.45	152.0	205.20
18.0	24.30	63.0	85.05	108.0	145.80	153.0	206.55
19.0	25.65	64.0	86.40	109.0	147.15	154.0	207.90
20.0	27.00	65.0	87.75	110.0	148.50	155.0	209.25
21.0	28.35	66.0	89.10	111.0	149.85	156.0	210.60
22.0	29.70	67.0	90.45	112.0	151.20	157.0	211.95
23.0	31.05	68.0	91.80	113.0	152.55	158.0	213.30
24.0	32.40	69.0	93.15	114.0	153.90	159.0	214.65
25.0	33.75	70.0	94.50	115.0	155.25	160.0	216.00
26.0	35.10	71.0	95.85	116.0	156.60	161.0	217.35
27.0	36.45	72.0	97.20	117.0	157.95	162.0	218.70
28.0	37.80	73.0	98.55	118.0	159.30	163.0	220.05
29.0	39.15	74.0	99.90	119.0	160.65	164.0	221.40
30.0	40.50	75.0	101.25	120.0	162.00	165.0	222.75
31.0	41.85	76.0	102.60	121.0	163.35	166.0	224.10
32.0	43.20	77.0	103.95	122.0	164.70	167.0	225.45
33.0	44.55	78.0	105.30	123.0	166.05	168.0	226.80
34.0	45.90	79.0	106.65	124.0	167.40	169.0	228.15
35.0	47.25	80.0	108.00	125.0	168.75	170.0	229.50
36.0	48.60	81.0	109.35	126.0	170.10	171.0	230.85
37.0	49.95	82.0	110.70	127.0	171.45	172.0	232.20
38.0	51.30	83.0	112.05	128.0	172.80	173.0	233.55
39.0	52.65	84.0	113.40	129.0	174.15	174.0	234.90
40.0	54.00	85.0	114.75	130.0	175.50	175.0	236.25
41.0	55.35	86.0	116.10	131.0	176.85	176.0	237.60
42.0	56.70	87.0	117.45	132.0	178.20	177.0	238.95
43.0	58.05	88.0	118.80	133.0	179.55	178.0	240.30
44.0	59.40	89.0	120.15	134.0	180.90	179.0	241.65
45.0	60.75	90.0	121.50	135.0	182.25	180.0	243.00

FIG. 125.—"CORRECTED WEIGHT" TABLE

figured on the assumption that 122 pounds of usable paper would be used, the group earns a certain premium as a reward for the care exercised to minimize scrap.

In computing premium earnings, the "corrected weight" of the paper consumed minus the weight of the scrap formed serves as a measure of pay units, and so becomes a factor in

the convenient formula evolved for calculating the total premium time earned by the workers, which follows:

$$P = \frac{T - t}{2}$$

Where;

P = Total group premium time.
T = The product of the "Time Basis" multiplied by the number of pay units earned by the group (ascertained from the "Weight Table").
t = Sum of the hours worked by the individual members of the group.

The "Time Basis" is taken as one hour, or one and two-thirds times the average time for consuming a pound of usable paper by two machines, as pro-rated per person in an organization of nine, as previously explained. Then, "T" becomes equal in numerical value to the number of pay units earned by the group, as obtained directly from the "Weight Table." The object of multiplying the rate at which a pound of paper from the two machines is credited to each member of the working group by 1⅔ is to secure for the workers attaining task production a premium of one-third their base rates of pay, as an incentive for application to task.

An individual's premium earnings are equal to the individual's premium time multiplied by the individual's day rate of recompense, the formula for which is:

$$P' = \frac{P \times G \times R}{t}$$

Where;

P' = Individual's premium earnings.
P = Total group premium time.
G = Hours worked by individual.
R = Individual's day rate.
t = Sum of the hours worked by the individual members of the group.

Such a method of regulating the earnings by taxing waste of time and material is not only bound to be productive of benefits to the workers in the form of increased earnings, but also to the management in the form of decreased cost. A full appreciation of the benefits necessitates a record of the betterment realized. Such a record is given in the table shown in Fig. 126, from which it is very evident that during the month such investigation was made the premium earnings of the blue-print gang were quite substantial—somewhat over 35 per cent., on the average—and that the improvement became more marked as the workers acquired skill through interest and application. If the difference between the "corrected weight" of paper used and the sum of the weights of the usable paper consumed

DATE	WEIGHT OF PAPER USABLE CONSUMED lbs.	CORRECTED WEIGHT lbs.	SCRAP lbs.	SIZE OF GROUP	TIME BASIS X NO. PAY UNITS T	SUM OF ALL HOURS WORKED—GROUP t	GROUP PREMIUM TIME P	PREMIUM Per Cent
Sept. 17	94	126	25	9	101	72	14.4	20.0
18	105	141	33	9	108	72	18.	25.
20	115	155	29	9	126	72	27.	37.5
21	63	85	13	9	72	36	18.	50.
23	136	183	39	10	144	80	32.	40.
25	105	141	28	10	113	72	20.5	28.5
26	84	113	23	9	90	72	9.	12.5
27	84	113	23	9	90	72	9.	12.5
28	63	85	16	9	69	36	16.2	45.
30	115	155	31	10	124	80	22.	27.5
Oct. 1	147	198	40	11	158	80	39.	47.8
2	115	155	30	10	125	76	24.6	32.4
3	94	128	20	9	108	72	18.	25.
4	105	141	29	8	112	64	24.	37.5
5	52	70	14	7	56	28	14.	50.
7	63	85	13	7	72	48	12.	25.
8	126	170	42	10	128	64	32.	50.
9	136	183	39	10	144	72	36.	50.
10	126	170	36	9	144	72	36.	50.
11	94	126	25	10	101	72	14.4	20.
12	63	85	13	8	72	32	20.	62.5
14	105	141	29	9	112	64	24.	37.5
15	63	85	15	7	70	56	7.	12.5
16	84	113	24	7	89	52	18.5	35.6
18	84	113	29	6	84	46	18.	39.2
19	31	41	8	6	33	22	5.4	24.5
						AVERAGE		33.38

FIG. 126.—PREMIUM RECORDS—BLUE-PRINT DEPARTMENT

and the scrap is taken as measuring the amount of paper saved, the saving during the month totaled to some 184 pounds of blue-print paper. Though the gain was principally in the increased rate of production, saving of time, as indicated by the value of the premiums earned for bettering task time, the value of the paper saved amounted to no inconsiderable sum. This saving, 184 pounds, would represent very nearly 900 yards of the 42-inch blue-print paper employed.

The same method of rating tasks by taxing waste, or paying premiums for minimizing scrap, can be profitably adopted in a great variety of industries and for numerous tasks: for instance, in the manufacture of paper boxes, the production cost of which is materially increased by unnecessary scrap.

Without going into a detailed explanation of the procedure of paper-box manufacture or of the operation of paper-making machines, it may be simply mentioned that the operation is a machine one and that the production per machine during any period may be directly ascertained from the counter readings registering the number of cycles of the constructing mechanism of the machine. A common rating is for the counter to register a unit for each twenty boxes constructed, and such relationship may be taken as an operating standard for the purpose of explaining the method of computing earnings.

The first requirement in introducing the method of basing a premium upon the minimizing of scrap in machine paper-box making is to standardize the sizes of boxes, ascertain by careful study the exact amount of material entering their construction and by production studies arrive at a reasonable percentage allowance for scrap. As in the case of blue printing, the measure of the material utilized and the amount of scrap resulting are best expressed in terms of weight. That is, the average weights of the material productively utilized and that represented by the accumulated scrap has to be ascertained by production studies. Unlike the application of the principle to blue printing, however, the utilized material is subsequently measured by the number of boxes constructed of specific size and only the weight of the scrap measured. The weight of scrap is subsequently expressed in the number of boxes such weight of material would form, could it be completely utilized for such purpose.

Also, the machine manufacture of paper boxes lends itself to a straight piece-work system of recompense, so the premium takes the form of a certain number of extra boxes—the number depending upon the percentage of the material utilized that is

converted into scrap—for which the machine operator is paid at regular piece-work rate.

In one manufacturing plant where there is an inducement for minimizing the amount of scrap formed in paper-box manufacture—taxing waste—eight different types of boxes are made,

CONVERSION OF POUNDS OF SCRAP INTO THOUSANDS OF BOXES

POUNDS SCRAP	TYPE OF BOX							
	A	B	C	D	E	F	G	H
10	.1	.1	.1	.1	.1	.5	.2	.6
20	.2	.2	.2	.2	.3	1.1	.3	1.3
30	.3	.3	.3	.3	.4	1.6	.5	1.9
40	.4	.4	.4	.4	.6	2.1	.7	2.5
50	.5	.6	.6	.5	.7	2.6	.9	3.1
60	.6	.7	.7	.6	.9	3.2	1.0	3.8
70	.7	.8	.8	.7	1.0	3.7	1.2	4.4
80	.8	.9	.9	.8	1.2	4.2	1.4	5.0
90	.8	1.0	1.0	.9	1.3	4.8	1.5	5.6
100	.9	1.1	1.1	1.0	1.5	5.3	1.7	6.3
110	1.0	1.2	1.2	1.1	1.6	5.8	1.9	6.9
120	1.1	1.3	1.3	1.2	1.8	6.4	2.1	7.5
130	1.2	1.5	1.5	1.3	1.9	6.9	2.2	8.2
140	1.3	1.6	1.6	1.4	2.1	7.4	2.4	8.8
150	1.4	1.7	1.7	1.5	2.2	7.9	2.6	9.4
160	1.5	1.8	1.8	1.6	2.4	8.5	2.7	10.0
170	1.6	1.9	1.9	1.7	2.5	9.0	2.9	10.7
180	1.7	2.0	2.0	1.8	2.7	9.5	3.1	11.3
190	1.8	2.1	2.1	1.9	2.8	10.0	3.3	11.9
200	1.9	2.2	2.2	2.0	3.0	10.6	3.4	12.5
220	2.0	2.5	2.5	2.2	3.3	11.6	3.8	13.8
240	2.2	2.7	2.7	2.4	3.6	12.7	4.1	15.0
260	2.4	2.9	2.9	2.6	3.9	13.6	4.5	16.3
280	2.6	3.1	3.1	2.8	4.2	14.8	4.8	17.5
300	2.8	3.4	3.4	3.0	4.5	15.9	5.1	18.8
320	3.0	3.6	3.6	3.2	4.8	16.9	5.5	20.0
340	3.2	3.8	3.8	3.4	5.1	18.0	5.8	21.3
360	3.4	4.0	4.0	3.6	5.4	19.0	6.2	22.6
380	3.6	4.3	4.3	3.8	5.7	20.0	6.5	23.8
400	3.8	4.5	4.5	4.0	6.0	21.2	6.9	25.1
420	3.9	4.7	4.7	4.2	6.3	22.2	7.2	26.3
440	4.1	4.9	4.9	4.4	6.6	23.3	7.5	27.5
460	4.3	5.2	5.2	4.6	6.9	24.3	7.9	28.8
480	4.5	5.4	5.4	4.8	7.2	25.4	8.2	30.1
500	4.7	5.6	5.6	5.0	7.5	26.5	8.6	31.3

FIG. 127.—SCRAP-CONVERSION TABLE

which, for convenience, may be referred to as Styles *A* to *H* inclusive. The piece rates, based on a thousand boxes, differ for a number of the types, and for some varieties both a machine operator and a helper are required, each of whom receives a different rate. The rates are, of course, established from records of careful time studies and are so proportioned that the diligent worker should receive about one-third more pay than if he were working on day rates.

The allowable scrap—the proportional amount of which is arrived at by production study—is set at 20 per cent. of the amount of material actually entering into the construction of the boxes. The conversion of the weight of scrap into the number of boxes such weight of material would make, were scrap entirely eliminated, is ascertained from recorded data in the form of conversion tables—see Fig. 127.

The method of computing the worker's earnings is to record the number of boxes made during the day—ascertained by noting the difference between the counter readings at the start and end of the work-day and multiplying it by 20, each unit of the counter reading registering the construction of 20 boxes —and multiply the output per machine by 1.20 to ascertain the number of boxes made plus the 20 per cent. allowance for scrap. The scrap accumulated per machine during the day is weighed and the equivalent number of boxes ascertained from the "Scrap-conversion Table." The scrap expressed in terms of boxes is then deducted from the number of boxes made increased by 20 per cent., and the worker receives pay at piece rates for the balance, though the number may considerably exceed the actual number of boxes made by him.

As an example, it may be assumed that the counter of a paper-box machine records during the working day 1,085 units, or the manufacture of 21,700 Type *D* boxes (1,085 × 20) and that the amount of scrap formed during the day totaled to 200 pounds. Increasing the number of boxes actually made by 20 per cent. gives 26,040, from which 2,000, the conversion of the 200 pounds of scrap into equivalent box measure (see "Conversion Table," Fig. 127), has to be deducted to arrive at the number of boxes with which the worker is credited as his day's output—*i. e.*, 26,040 − 2,000 = 24,040. The amount earned for the skill and care displayed in keeping down scrap is, then, the piece-rate pay on 2,340 boxes (24,040 − 21,700). Had the operator secured the same output with only 180 pounds of scrap, the amount earned for such application to his task and skill displayed would have represented the piece rate-pay on 2,540 boxes.

APPENDIX X

RATING SAWING-OFF METAL STOCK

APPENDIX X

RATING SAWING-OFF METAL STOCK

MOST metal-working establishments are compelled to saw-off stock for subsequent fabrication into mechanisms of one kind or another. Such simple operation is so general that rarely is it given much consideration. Low-priced labor is employed, usually on day work, for seldom is the operation conducted on the more effective piece-rate plan, or if some system of incentive plan is introduced, no particular attempt is made to secure high rates of production by establishing an accurate and equitable plan of inducement.

Rates for sawing-off operations on bars and structural shapes can be set, however, by time study that are highly effective in securing high rates of output and are very acceptable to the workers by virtue of the good earnings secured by the production realized when both work and recompense are measured in accurate and equitable units. The procedure entailed in arriving at such rates, by approved time-study methods, is well exemplified in the case of a manufacturing plant utilizing large quantities of round, square and rectangular bars and a number of structural steel members of standard section which have to be cut-off into measured lengths for use in the manufacture of certain product.

The problem was, briefly, to devise a method by which the work could be placed on an equitable incentive plan and an accurate measure of the work entailed in sawing-off the various shapes and sizes of bars established. Investigations indicated that where cold saws of the friction type, giving a very nearly constant saw-pressure on the work, were used, the mechanical cutting of the bars could be accurately measured in terms of the sectional area through which the saws cut and that for the line of bars cut, the time for sawing bars of equal cross-section area was very nearly the same, irrespective of the shape of the section. That is, the time required to cut through a round bar of a certain cross-section area was found to be practically the same as that required to cut through a square bar of equal section and similar material, or to cut through a bar of any

other shape, provided its cross-section area was the same. Machine time in sawing-off operations, it was thus seen, could be accurately standardized and predetermined, so an extended series of time studies was conducted to establish accurate measures of handling time, to check machine-time computations and to arrive at the necessary time allowances for preliminary operations, delays, etc.

With the machine speeds and the procedure standardized, the studies—conducted according to the approved methods described in Section I—furnished data from which curves were plotted to show the relationship between the cross-section area of the bar and the time consumed per cut, or machine time, and that existing between the average aggregate time for the various acts of preparation, etc., or handling time, and the cross-section areas of the bars.

The machine time per unit cross-section of bar was found, as would be expected, to be constant, for all practical purposes, though differing somewhat for soft and hard steels. A mean time, however, was selected as a basis for rating all—the difference in cutting time between the two varieties being provided for by adding a certain time allowance (10 per cent.) when cutting hard steel—varieties of steel bars cut and, as the average handling time was found to vary very nearly directly with the cross-section area of the bar, a straight inclined line plotted to the co-ordinates of time and cross-section area of bar depicts the total machine plus handling times per cut for progressive cross-section areas of bar. Such a straight line is designated by a simple equation that can be conveniently incorporated in a formula by which an accurate task time for any sawing-off operation can be predetermined, proper time allowances having been added to the established "minimum selected times" for both machine and handling operations.

The variable factors in the equation of the line depicting the relationship between cross-section area of the bars and the total time consumed in the cutting-off operations are, of course, time and area of bar. As time is the measure of both the rate of output and the rate for recompense on piece work, a constant is readily selected which when multiplied by the cross-section area of the bar gives a measure of the recompense earned per cut of bar. Such measure of recompense may be termed, for convenience, the number of "units," and when multiplied by the pay value of the unit gives the piece rate for cutting-off the particular bar. By suitable selection of the constant by which the cross-section area of the bar is multiplied, the resulting

number of units may give the piece rate directly, or, as is more customary, the constant may be so proportioned that the number of units multiplied by the unit rate of $0.01 gives the piece rate, necessitating simply the pointing off of two decimal places. Another advantage of such "unit" rating is that, should a change in the pay for the work be necessary, a corresponding change in the value of the "unit" is sufficient. The piece rate for sawing-off a number of bars at the same time—in one operation—is amenable to the same method of computation, by considering the aggregate cross-section area of the bars as a unit.

During the course of a day, an operator might be called upon to saw-off a variety of bars, or lots of bars, in which case a tally would be kept of the size and number of bars sawed on each cut and, at the end of the day, the piece rates are computed for each lot independently and totaled to ascertain the worker's earnings for the day.

To simplify the computation of piece rates, tables should be prepared giving the "units" corresponding to the cross-section area of each size and class of bar which might have to be cut. A series of such tables is given as Figs. 128 to 131 inclusive.

It will be noted in the tables shown in Figs. 128 and 129 that the areas for certain of the smaller bars, as given, are not true measures, but somewhat greater. The reason for this deviation is based on the fact that the handling time for small bars is proportionally greater, compared to the machine time, than for larger bars. In the tables, the increase in true cross-section area of bar is proportional to the required increase in "unit" measure, so the "units" corresponding to such "adjusted areas" provide the necessary additional allowance for the cuts.

The use of these "Unit Tables" in computing the earnings of the saw operators is most clearly demonstrated by considering them in connection with a tally sheet of a worker's output, an operator engaged on a diversity of cutting-off jobs, such as those shown on the tally sheet, Fig. 132.

The sheet is divided into sections by a central column in which are posted the data as to size and type of bars cut, the section to the left of which is filled in, as is also the central column, by the time clerk. In the column to the extreme left of the sheet are entered two sets of numbers, the first giving the number of pieces of a given size and shape that are produced, and the second the total number of cuts taken, including any entailed in cutting-off butt ends. In computing the workers'

COLD SAW
STEEL CUT-OFF AREAS AND UNITS

SIZE INCHES	SQUARE □ AREA	SQUARE □ UNITS	ROUND ○ AREA	ROUND ○ UNITS	SIZE INCHES	SQUARE □ AREA	SQUARE □ UNITS	ROUND ○ AREA	ROUND ○ UNITS
1/4	* .225	0.17	* .210	0.16	5-	25.0	8.10	19.5	6.40
3/8	* .280	0.19	* .250	0.18	1/4	27.5	8.90	21.5	7.05
1/2	* .340	0.21	* .315	0.20	1/2	30.0	9.80	23.5	7.70
5/8	* .410	0.23	* .380	0.22	3/4	33.0	10.5	26.0	8.40
3/4	.560	0.28	.440	0.24	6-	36.0	11.5	28.0	9.15
7/8	.765	0.35	.600	0.29	1/2	42.0	13.5	33.0	10.5
1-	1.00	0.42	.785	0.35					
1/8	1.25	0.51	.995	0.42					
1/4	1.55	0.60	1.20	0.49					
3/8	1.90	0.71	1.60	0.58					
1/2	2.25	0.82	1.75	0.67					
5/8	2.65	0.95	2.10	0.76					
3/4	3.05	1.10	2.40	0.87					
7/8	3.50	1.25	2.75	0.98					
2-	4.00	1.40	3.15	1.10					
1/8	4.50	1.55	3.55	1.25					
1/4	5.05	1.70	4.00	1.40					
3/8	5.65	1.90	4.30	1.50					
1/2	6.25	2.10	4.90	1.65					
5/8	6.90	2.30	5.40	1.85					
3/4	7.55	2.50	5.95	2.00					
7/8	8.25	2.75	6.50	2.20					
3-	9.00	2.95	7.05	2.35					
1/8	9.75	3.25	7.65	2.55					
1/4	10.5	3.50	8.30	2.75					
3/8	11.5	3.75	8.95	2.95					
1/2	12.0	4.00	9.60	3.20					
5/8	13.0	4.30	10.5	3.40					
3/4	14.0	4.60	11.0	3.65					
7/8	15.0	4.90	11.0	3.85					
4-	16.0	5.20	12.5	4.10					
1/4	18.0	5.90	14.0	4.65					
1/2	20.0	6.55	16.0	5.20					
3/4	22.5	7.30	17.5	5.75					

* Adjusted Area for Extra Allowance on Small Sizes.

FIG. 128.—SQUARE AND ROUND STEEL BAR CUT-OFF UNITS

COLD SAW
STEEL CUT - OFF AREAS AND UNITS

WIDTH INCHES	THICKNESS, INCHES													
	1/4		3/8		1/2		5/8		3/4		7/8		1	
	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS
1/2	* 0.25	0.18	* 0.32	0.20	* 0.32	0.20	*0.38	0.22	*0.41	0.23	0.44	0.24	0.50	0.26
3/4	* 0.28	0.19	* 0.34	0.21	* 0.41	0.23	*0.47	0.25	0.56	0.28	0.66	0.31	0.75	0.35
1	* 0.34	0.21	* 0.41	0.23	0.50	0.26	0.63	0.30	0.75	0.34	0.88	0.38	1.00	0.42
1-1/4	* 0.38	0.22	0.47	0.25	0.63	0.30	0.78	0.35	0.94	0.40	1.10	0.45	1.25	0.50
1-1/2	0.41	0.23	0.56	0.29	0.75	0.34	0.94	0.40	1.12	0.46	1.30	0.52	1.50	0.58
1-3/4	0.44	0.24	0.65	0.30	0.88	0.38	1.10	0.45	1.30	0.52	1.53	0.60	1.75	0.66
2	0.50	0.26	0.75	0.34	1.00	0.42	1.25	0.50	1.50	0.58	1.75	0.66	2.00	0.74
2-1/4	0.56	0.28	0.84	0.36	1.12	0.46	1.40	0.55	1.70	0.65	1.97	0.73	2.25	0.82
2-1/2	0.63	0.30	0.94	0.40	1.25	0.50	1.56	0.60	1.88	0.70	2.20	0.80	2.50	0.90
2-3/4	0.69	0.32	1.03	0.42	1.37	0.55	1.72	0.65	2.06	0.75	2.40	0.88	2.75	0.98
3	0.75	0.34	1.12	0.46	1.50	0.58	1.88	0.70	2.25	0.82	2.62	0.94	3.00	1.06
3-1/4	0.81	0.36	1.22	0.49	1.63	0.62	2.03	0.75	2.44	0.88	2.85	1.00	3.25	1.15
3-1/2	0.88	0.38	1.30	0.52	1.75	0.66	2.20	0.80	2.62	0.94	3.06	1.07	3.50	1.22
3-3/4	0.94	0.40	1.40	0.55	1.88	0.70	2.35	0.85	2.80	1.00	3.28	1.15	3.75	1.30
4	1.00	0.42	1.50	0.58	2.00	0.74	2.50	0.90	3.00	1.06	3.50	1.22	4.00	1.39
4-1/4	1.05	0.44	1.60	0.61	2.12	0.77	2.66	0.95	3.20	1.12	3.72	1.30	4.25	1.45
4-1/2	1.12	0.46	1.70	0.65	2.25	0.82	2.82	1.00	3.37	1.18	3.94	1.36	4.50	1.55
4-3/4	1.20	0.48	1.77	0.66	2.37	0.86	2.97	1.05	3.56	1.24	4.15	1.44	4.75	1.62
5	1.25	0.50	1.88	0.70	2.50	0.90	3.13	1.10	3.75	1.30	4.38	1.50	5.00	1.70
5-1/4	1.30	0.52	1.97	0.73	2.62	0.94	3.28	1.15	3.94	1.35	4.60	1.57	5.25	1.77
5-1/2	1.38	0.54	2.05	0.75	2.75	0.98	3.44	1.20	4.13	1.42	4.80	1.64	5.50	1.85
5-3/4	1.45	0.56	2.15	0.80	2.88	1.02	3.60	1.25	4.30	1.48	5.03	1.70	5.75	1.95
6	1.50	0.58	2.25	0.82	3.00	1.06	3.75	1.30	4.50	1.54	5.25	1.77	6.00	2.02
6-1/4	1.55	0.60	2.35	0.85	3.13	1.10	3.90	1.35	4.70	1.60	5.47	1.85	6.25	2.10
6-1/2	1.62	0.62	2.45	0.88	3.25	1.14	4.06	1.40	4.88	1.66	5.70	1.92	6.50	2.18
6-3/4	1.70	0.64	2.55	0.91	3.37	1.18	4.22	1.45	5.06	1.72	5.90	2.00	6.75	2.26
7	1.75	0.66	2.63	0.95	3.50	1.22	4.37	1.50	5.25	1.77	6.12	2.05	7.00	2.34

* Adjusted Area for Extra Allowance on Small Sizes.

FIG. 129.—RECTANGULAR STEEL BAR CUT-OFF UNITS

COLD SAW
STEEL CUT - OFF AREAS AND UNITS

WIDTH INCHES	THICKNESS, INCHES															
	1-1/8		1-1/4		1-3/8		1-1/2		1-5/8		1-3/4		1-7/8		2	
	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS
1/2	0.56	0.28	0.63	0.30	0.69	0.32	0.75	0.34	0.81	0.37	0.88	0.38	0.94	0.40	1.00	0.42
3/4	0.85	0.37	0.94	0.40	1.03	0.43	1.12	0.46	1.22	0.49	1.30	0.52	1.41	0.56	1.50	0.58
1	1.12	0.46	1.25	0.50	1.38	0.55	1.50	0.58	1.63	0.62	1.75	0.66	1.88	0.70	2.00	0.74
1-1/4	1.40	0.55	1.56	0.60	1.72	0.65	1.88	0.70	2.03	0.75	2.20	0.80	2.35	0.85	2.50	0.90
1-1/2	1.70	0.65	1.88	0.70	2.05	0.77	2.25	0.82	2.44	0.88	2.62	0.94	2.82	1.00	3.00	1.06
1-3/4	1.97	0.73	2.20	0.80	2.40	0.88	2.62	0.94	2.85	1.00	3.06	1.08	3.28	1.15	3.50	1.22
2	2.25	0.82	2.50	0.90	2.75	1.00	3.00	1.06	3.25	1.14	3.50	1.22	3.75	1.30	4.00	1.38
2-1/4	2.53	0.90	2.80	1.00	3.10	1.10	3.38	1.18	3.66	1.27	3.95	1.35	4.22	1.45	4.50	1.55
2-1/2	2.80	1.00	3.13	1.10	3.44	1.20	3.75	1.30	4.06	1.40	4.38	1.50	4.70	1.60	5.00	1.70
2-3/4	3.10	1.10	3.44	1.20	3.77	1.31	4.13	1.42	4.47	1.53	4.80	1.65	5.16	1.75	5.50	1.85
3	3.37	1.18	3.75	1.30	4.13	1.44	4.50	1.55	4.88	1.66	5.25	1.77	5.63	1.90	6.00	2.02
3-1/4	3.66	1.27	4.05	1.40	4.47	1.53	4.88	1.66	5.28	1.80	5.70	1.92	6.10	2.05	6.50	2.18
3-1/2	3.93	1.35	4.38	1.50	4.80	1.65	5.25	1.77	5.70	1.92	6.12	2.06	6.55	2.20	7.00	2.34
3-3/4	4.22	1.45	4.70	1.60	5.15	1.75	5.63	1.90	6.10	2.05	6.55	2.20	7.03	2.36	7.50	2.50
4	4.50	1.55	5.00	1.70	5.50	1.85	6.00	2.02	6.50	2.18	7.00	2.33	7.50	2.50	8.00	2.66
4-1/4	4.77	1.63	5.30	1.80	5.85	1.97	6.36	2.15	6.90	2.30	7.44	2.48	7.97	2.65	8.50	2.82
4-1/2	5.05	1.73	5.63	1.90	6.20	2.08	6.75	2.25	7.30	2.44	7.88	2.62	8.44	2.80	9.00	2.98
4-3/4	5.35	1.80	5.95	2.00	6.55	2.20	7.12	2.37	7.72	2.57	8.32	2.77	8.90	2.95	9.50	3.14
5	5.63	1.90	6.25	2.10	6.88	2.30	7.50	2.50	8.13	2.70	8.75	2.90	9.40	3.10	10.00	3.30
5-1/4	5.90	2.00	6.55	2.20	7.22	2.40	7.88	2.62	8.55	2.82	9.20	2.95	9.85	3.25	10.50	3.45
5-1/2	6.20	2.08	6.88	2.30	7.55	2.52	8.25	2.75	8.95	2.96	9.63	3.10	10.30	3.40	11.00	3.62
5-3/4	6.46	2.18	7.20	2.40	7.90	2.62	8.63	2.86	9.35	3.10	10.10	3.33	10.[illegible]0	3.5[illegible]	11.50	3.77
6	6.76	2.25	7.50	2.50	8.25	2.75	9.00	2.98	9.75	3.22	10.50	3.65	11.20	3.70	12.00	3.95
6-1/4	7.03	2.35	7.80	2.60	8.60	2.85	9.36	3.10	10.15	3.33	11.05	3.62	11.70	3.85	12.50	4.00
6-1/2	7.30	2.44	8.13	2.70	8.93	2.95	9.75	3.22	10.65	3.46	11.45	3.76	12.20	4.02	13.00	4.25
6-3/4	7.60	2.53	8.44	2.80	9.30	3.07	10.15	3.33	11.00	3.62	11.80	3.86	12.70	4.15	13.50	4.42
7	7.88	2.62	8.75	2.90	9.65	3.18	10.50	3.45	11.40	3.75	12.25	4.00	13.10	4.30	14.00	4.58

FIG. 129.—RECTANGULAR STEEL BAR CUT-OFF UNITS (*Continued*)

COLD SAW — STEEL CUT - OFF AREAS AND UNITS																
	THICKNESS, INCHES															
WIDTH INCHES	2-1/8		2-1/4		2-3/8		2-1/2		2-5/8		2-3/4		2-7/8		3	
	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS	AREA	UNITS
1/2	1.06	0.44	1.12	0.46	1.20	0.48	1.25	0.50	1.30	0.52	1.37	0.55	1.44	0.56	1.50	0.58
3/4	1.60	0.61	1.70	0.65	1.77	0.67	1.88	0.70	1.97	0.74	2.06	0.78	2.15	0.80	2.25	0.82
1	2.12	0.77	2.25	0.82	2.38	0.86	2.50	0.90	2.62	0.93	2.75	0.98	2.88	1.03	3.00	1.06
1-1/4	2.66	0.95	2.82	1.00	2.96	1.05	3.13	1.10	3.28	1.16	3.44	1.20	3.60	1.25	3.75	1.32
1-1/2	3.20	1.12	3.38	1.18	3.55	1.25	3.75	1.30	3.95	1.35	4.12	1.40	4.33	1.48	4.50	1.54
1-3/4	3.70	1.29	3.95	1.35	4.15	1.43	4.38	1.50	4.60	1.57	4.82	1.65	5.05	1.70	5.25	1.80
2	4.25	1.46	4.50	1.55	4.75	1.62	5.00	1.70	5.25	1.77	5.50	1.86	5.75	1.96	6.00	2.02
2-1/4	4.77	1.63	5.05	1.75	5.35	1.81	5.62	1.90	5.90	2.00	6.18	2.08	6.46	2.18	6.76	2.28
2-1/2	5.30	1.80	5.62	1.90	5.95	2.00	6.25	2.10	6.55	2.20	6.88	2.30	7.17	2.40	7.50	2.50
2-3/4	5.85	1.97	6.18	2.08	6.55	2.20	6.88	2.30	7.22	2.40	7.55	2.53	7.90	2.62	8.25	2.75
3	6.40	2.15	6.76	2.25	7.12	2.37	7.50	2.50	7.88	2.62	8.25	2.75	8.62	2.86	9.00	2.98
3-1/4	6.90	2.31	7.32	2.44	7.72	2.57	8.11	2.70	8.55	2.82	8.95	2.95	9.35	3.08	9.75	3.25
3-1/2	7.44	2.48	7.88	2.62	8.32	2.75	8.75	2.90	9.19	3.05	9.62	3.17	10.05	3.33	10.50	3.45
3-3/4	7.97	2.65	8.44	2.80	8.90	2.95	9.38	3.10	9.85	3.24	10.32	3.40	10.80	3.55	11.25	3.72
4	8.50	2.82	9.00	2.98	9.50	3.14	10.00	3.30	10.50	3.45	11.00	3.62	11.50	3.77	12.00	3.95
4-1/4	9.05	3.00	9.55	3.16	10.10	3.33	10.60	3.50	11.15	3.68	11.70	3.85	12.20	4.00	12.75	4.18
4-1/2	9.55	3.16	10.10	3.33	10.70	3.52	11.25	3.70	11.80	3.88	12.40	4.07	12.95	4.23	13.50	4.42
4-3/4	10.10	3.33	10.68	3.53	11.30	3.70	11.90	3.90	12.45	4.10	13.05	4.30	13.65	4.48	14.25	4.68
5	10.60	3.50	11.25	3.70	11.90	3.90	12.50	4.10	13.10	4.30	13.75	4.52	14.40	4.70	15.00	4.90
5-1/4	11.15	3.66	11.80	3.88	12.46	4.10	13.10	4.30	13.80	4.52	14.45	4.71	15.10	4.93	15.75	5.15
5-1/2	11.70	3.85	12.40	4.05	13.05	4.28	13.75	4.50	14.40	4.70	15.10	4.94	15.80	5.15	16.50	5.38
5-3/4	12.20	4.00	12.95	4.24	13.60	4.47	14.40	4.70	15.10	4.94	15.80	5.16	16.55	5.40	17.25	5.65
6	12.75	4.18	13.50	4.42	14.25	4.66	15.00	4.90	15.75	5.15	16.50	5.38	17.25	5.64	18.00	5.88
6-1/4	13.30	4.35	14.05	4.60	14.85	4.88	15.60	5.10	16.40	5.35	17.20	5.60	17.95	5.85	18.75	6.12
6-1/2	13.80	4.52	14.60	4.77	15.45	5.05	16.25	5.30	17.05	5.57	17.90	5.83	18.70	6.08	19.50	6.33
6-3/4	14.30	4.70	15.18	4.95	16.08	5.26	16.90	5.50	17.70	5.76	18.55	6.05	19.40	6.31	20.25	6.60
7	14.90	4.85	15.75	5.15	16.60	5.42	17.50	5.70	18.40	6.00	19.25	6.30	20.12	6.53	21.00	6.82

FIG. 129.—RECTANGULAR STEEL BAR CUT-OFF UNITS (*Continued*)

earnings, the necessary number of butt-end cuts are counted as well as the number of cuts to length, for it is obvious that the trimming-off of butts consumes as much time as do the productive parting cuts. In the other two columns posted on the job are recorded the number of pieces sawed per cut and the total number of cuts taken, including the butt-end cuts.

COLD SAW

STEEL CUT-OFF AREAS AND UNITS.

SIZE			AREA	UNITS	SIZE			AREA	UNITS
3/4	3/4	1/8	0.17	0.13	3-1/2	2-1/2	1/4	1.44	0.56
1	1	1/8	0.23	0.18	3-1/2	2-1/2	3/8	1.78	0.67
1	1	3/16	0.34	0.21	3-1/2	2-1/2	5/16	2.11	0.78
1-1/4	1-1/4	3/16	0.43	0.24	3	3	1/4	1.44	0.56
1-1/4	1-1/4	1/4	0.56	0.28	3	3	3/8	2.11	0.78
1-1/2	1-1/2	1/8	0.36	0.22	3-1/2	3	5/16	1.13	0.72
1-1/2	1-1/2	3/16	0.53	0.27	3-1/2	3	3/8	2.30	0.84
1-1/2	1-1/2	1/4	0.69	0.32	3-1/2	3-1/2	3/8	2.48	0.90
1-3/4	1-3/4	3/16	0.62	0.30	4	3	1/4	1.69	0.64
1-3/4	1-3/4	1/4	0.81	0.36	4	3	5/16	2.09	0.77
2	1-1/2	1/4	0.81	0.36	4	3	3/8	2.48	0.90
2	2	1/4	0.48	0.25	4	4	3/8	2.86	1.02
2	2	3/16	0.71	0.33	5	3	3/8	2.86	1.02
2	2	1/4	0.94	0.40	5	3-1/2	3/8	3.05	1.08
2-1/4	2-1/4	1/4	0.98	0.42	5	5	3/8	3.61	1.25
2-1/2	2	3/16	0.81	0.36	6	4	3/8	3.61	1.25
2-1/2	2	1/4	1.06	0.44					
2-1/2	2-1/2	3/16	0.90	0.39					
2-1/2	2-1/2	1/4	1.19	0.48					
3	2	1/4	1.19	0.48					
3	2-1/2	1/4	1.31	0.52					
3	2-1/2	3/8	1.92	0.72					

FIG. 130.—ANGLE STEEL BAR CUT-OFF UNITS

In the first three columns reserved for the computation of earnings, to the right of the central stock column, are entered the areas sawed through per cut and the "units" corresponding to the *cut areas*, as given in the "Unit Tables" and the total number of "units," obtained by multiplying the number of "units" per cutting area by the number of cuts. In the column to the extreme right of the sheet are entered the "pay units" for the various lots, which are equal to the total number of "units" as computed plus one extra "unit" to cover time spent in changing from work on one order to work on the next requisition.

The data and computations for the first lot of ¾-inch square bar stock hardly requires further explanation. The first figure

in the column to the left of the sheet gives the number of pieces cut and the second number of the column is the same, as no butt ends were removed. The adjacent column shows that the bars were sawed one at a time and consequently the number of cuts in the following column is the same as the number of pieces. The area and "unit" entrees are obtained directly from the

COLD SAW

STEEL CUT - OFF AREAS AND UNITS.

I-BEAMS			CHANNELS		
DEPTH	AREA	UNITS	SIZE	AREA	UNITS
3	1.63	0.62	1	0.40	0.23
4	2.21	0.80	3	1.20	0.49
5	2.87	1.00	4	1.55	0.60
6	3.61	1.25	5	1.95	0.73
7	4.42	1.50	6	3.00	1.66
8	5.12	1.75	7	2.80	1.00
9	6.31	2.12	8	3.35	1.17
10	6.54	2.20	9	3.90	1.35
12	9.26	3.00	10	4.50	1.54
15	10.90	3.58	12	7.25	2.42
18	14.10	4.63	15	10.50	3.48
20	19.10	6.28			
21	17.68	5.73			
24	21.70	7.05			

FIG. 131.—I-BEAM AND CHANNEL STEEL CUT-OFF UNITS

"Unit Table," Fig. 128, and the total number of "units" is the product of the number of "units" corresponding to the cut area, 0.560 square inch, multiplied by the number of cuts, 8. The number of "pay units" is then one "unit" greater, or 3.24. The computations for the second lot cut are similar, but somewhat more involved, for the 12 pieces of 4-inch round steel stock produced required 3 butt-end cuts, so making the total number of cuts taken 15 and necessitating the multiplication of

the "unit" per cut area by 15, instead of by the number of pieces produced.

The computations of the "pay units" for the 24 pieces of 1-inch round steel stock bring in another factor. As 3 butt

DATE 12-29-18
SHIFT Day

STEEL CUTTING OFF
COLD SAW PRODUCTION TALLY SHEET

OPERATORS NAME AND NO. 41144 Doe, John

S PIECES FINISHED INCLUDING BUTT ENDS	C No. OF PIECES PER CUT	N No. OF CUTS N=S/C	SIZE	A AREA OF ONE PIECE TIMES "C"	U UNIT ON CHART TO "A"	T TOTAL UNITS T=U×N	P PAY UNITS P=T+1.0
8 8	1	8	3/4" Sq	0.560	0.28	2.24	3.24
12 15	1	15	4" Rd	12.50	4.10	61.50	62.50
1 1	1	1	1 7/8" Rd	2.75	0.95	0.95	1.95
24 27	3	9	1" Rd	2.35	0.87	7.83	8.83
4 4	1	4	3" Rd.	7.05	2.35	9.40	10.40
15 18	2	9	1 1/4" Sq.	3.05	1.10	9.90	10.90
6 8	1	8	1 7/8 Sq	3.50	1.25	10.00	11.00
7 8	1	8	2" x 1"	2.00	0.74	5.92	6.92
19 20	1	20	2 1/2" x 3/8"	0.94	0.40	8.00	9.00
5 8	1	8	5" x 3/4"	3.75	1.30	10.40	11.40
5 6	1	6	4" x 1 3/8"	5.50	1.85	11.10	12.10
3 3	1	3	6" x 2 3/8"	14.25	4.66	13.98	14.98
24 24	4	6	2 1/2" x 2 1/2" x 3/16"	3.60	1.25	7.50	8.50
16 24	3	8	1 3/4" x 1 3/4" x 1/4"	2.43	0.90	7.20	8.20
3 3	1	3	10" I	6.54	2.20	6.60	7.20
1 2	1	3	20" I	19.10	6.28	18.84	19.84
30 36	3	12	1" ⊔	1.20	0.49	5.88	6.88
21 27	3	9	4" ⊔	4.65	1.54	13.86	14.86
10 11	1	11	6" ⊔	3.00	1.06	11.66	12.66
5 5	1	5	8" ⊔	3.35	1.17	5.85	6.85
3 4	1	4	10" ⊔	4.50	1.54	6.16	7.16
30 36	3	12	1" ⊔	1.20	0.49	5.88	6.88

TALLYMAN J.R.   TOTAL 262.28

FIG. 132.—PRODUCTION TALLY SHEET—STEEL CUT-OFF

ends have to be removed, the total number of pieces severed is 27, but as 3 bars are cut at the same time only 9 cuts were required. The cut area is then three times that of a 1-inch

round bar, and the "unit"—see Fig. 128—corresponds to that for this larger area, 2.35 square inches. Multiplying the "unit" value by 9 gives the "total units," and adding one more unit gives the number of "pay units" for the lot. The computations for the 30 pieces of 1-inch channel, producing three butt ends, are exactly similar, except that the cut area and corresponding "unit" are obtained from the "Unit Table" given as Fig. 131.

The number of "pay units" for the various lots entered on the tally sheet, Fig. 132, representing the output from two saws in charge of the operator, total to 262.28, so, if the rate in force should be $0.01 per "unit," the operator's earnings for the work recorded would amount to $2.62.

The foregoing explanation of the application of an accurate piece-work system to the simple operation of sawing-off bar stock well demonstrates its convenience, and the economies to be realized by its adoption are forcibly brought out by records taken of the output and earnings of the workers of the cut-off shop, before and after its introduction.

Before the system was introduced, when the department was conducted on a day-work basis, a total of 588.70 man hours was required to cut through 22,170 square inches of cross-section area. Such rate of production represents an average of 37.65 square inches of cross-section area cut each hour per man. On the introduction of piece work but 332.60 man hours were required to cut through 38,722 square inches of cross-section area, or 116.40 square inches were cut through, on the average, each hour per man.

APPENDIX XI

RATING OPERATIONS ON AN AUTOMATIC DOVETAIL JOINTER

APPENDIX XI

RATING OPERATIONS ON AN AUTOMATIC DOVETAIL GLUE JOINTER

AN interesting example of a method of rating a special operation on wood-working machinery is one devised for the task of making-up, from narrower boards, boarding of specified width for the construction of packing cases and boxes. By the use of an automatic dovetailing and glueing machine, operated in conjunction with an ordinary power rip saw, the fairly complex operation is made very nearly automatic. The automatic machine dovetails the narrow boards, applies the glue and fits them together to form firm made-up boarding of the variety illustrated in Fig. 133, the rip saw simply functioning to reduce the made-up boarding to the desired width.

Two endless chain conveyors, or carriers, one operating from

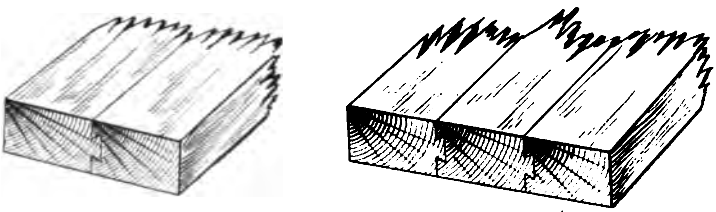

FIG. 133.—DOVETAILED BOARDING

either end of the automatic machine, convey the rough boards and the make-up boards, respectively, past the cutting mechanisms to the central section of the machine, where, after the glue has been applied to the tongues and grooves, the boards are fitted together and are delivered in the form of made-up boarding—to be reduced to the desired width by the rip saw. The carrier dogs may be set for various links of the conveyors, so economically accommodating assorted boards of different lengths.

A leader and three helpers constitute the force required to operate the equipment, as diagrammatically indicated in Fig. 134. Helper "*A*" feeds the rough boards of assorted lengths to the automatic machine, placing a board between each suc-

cessive pair of carrier dogs attached to the endless chain leading from his end of the machine—*i. e.*, if no delays occur. The leader receives the made-up boards, passes them to the rip saw or, if more than two boards are required to make up the required width of boarding, shunts made-up boards of insufficient width to helper "*C*" for use as make-up boards. Helper "*B*" receives the finished boarding from the rip saw and places it on the finished work truck and also passes the trims of sufficient

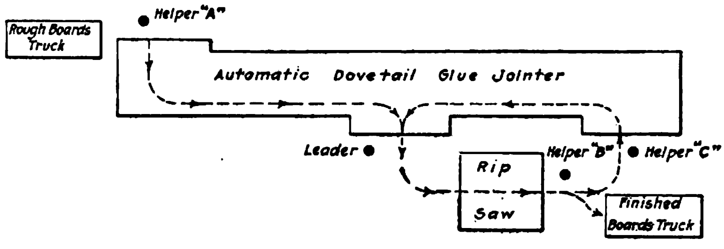

FIG. 134.—DIAGRAMMATIC ARRANGEMENT OF AUTOMATIC DOVETAIL MACHINE

width for make-up boards to helper "*C*," while the duties of helper "*C*" are simply to feed the make-up boards to the automatic machine.

The operation is chiefly a machine one, semi-automatic in character, and the work entailed is obviously measured by the number of rough boards fed to the machine by helper "*A*." The machine time, if no delays occur, is proportional to the carrier speed of the automatic machine and can be accurately predetermined. The handling time, or handling procedure, can be standardized, time-studied and rated and the necessary time allowances and delays ascertained, so the rating of what at first appears to be quite a complicated operation entails only a logical application of approved time-study procedure. However, as the operation is a rather unusual one, a résumé of the necessary studies and of the methods of adapting time-study procedure to the problem will serve to illustrate further the wide and varied field for time study as a basis for rate setting.

Standardization of procedure and equipment is the first essential, including the calibration of the machines for correct speeds, etc., then, by approved time-study methods, the necessary time allowances, including the allowance for the preparatory operations, should be established — such as the time required for oiling the machine, filling grease cups,

mixing glue and filling the glue tanks at regular intervals and for the necessary delays due to sweeping up shavings, making out time tickets, etc., and for personal delays, including that entailed in washing up at noon and night. These preparatory operations, allowable delays, etc., involve so much time during each working day which could otherwise be productively employed that they may be termed "necessary delays," for which suitable provision must be made in establishing proper rates for the work.

The second time-consuming operation for which an allowance has to be made is that of setting up the equipment for handling various lengths of boards. The carrier dogs have to be set so as to convey most economically the boards of certain assorted lengths, necessitating more or less adjustment and manipulation of the automatic machine, depending upon the particular variety of machine employed, the rip saw has to be set and a board tried for width, etc. This set of preparatory operations has to be repeated for each set-up of the machine equipment and, though the time required is practically constant for any set-up within the capacity of the standard machine, a time allowance—ascertained by time study and including a suitable "variation allowance"—must be, consequently, established and rated as an independent factor, one influencing the pay for the dovetailing work each time a new set-up is required.

Still another act preparatory to the actual starting up of the machine for productive operation is to move the truck of rough boards to the receiving end of the automatic machine. This simple act has to be performed after each machine set-up, so consumes time which might otherwise be productively utilized, necessitating a definite time allowance—established by time study—for its accomplishment. Should additional supplies of rough boards be required subsequently, during the actual operation of the machine on the same set-up, a fresh truck load can be supplied by assistants without arresting the productive operation of the machine, so a time allowance for such moving of the loaded, rough board truck need be provided but once for each set-up of the machine. As obviously the set-up of the automatic machine so far as accommodating various assorted lengths of boards—within the capacity of the standard machine—is concerned does not influence to any appreciable extent the time required to move the truck of rough boards, the time allowance for such act is constant for any machine set-up—*i. e.*, for any standard length of board. The customary allowance of 25 per cent. should be added to the "selected

time," however, as is customary for all handling operations of such nature.

The time entailed in feeding the boards to the machine, the operation of the dovetailing machine and the subsequent operation of sawing the made-up boarding to desired width should then be established by approved production time-study methods and a 5 per cent. time allowance added for such machine operation. This machine time will differ for each machine set-up.

Finally, a time allowance must be provided for the concluding operation of removing the truck of finished boarding at the completion of each run on a machine set-up. The finished boarding may be trucked to a planer for subsequent finish, or simply stacked in the vicinity of the dovetailing machine, but should be removed to provide room for the next machine set-up and to segregate the boarding of certain widths, so the time required for such removal rightfully becomes a charge against possible operating time of the machine. That is, after the run of each set-up, time is spent in removing finished boarding, preparatory of another set-up, that might otherwise be devoted to the productive operation of the machine. Of course, if finished made-up boarding should be required during the run of a set-up, it could be secured by assistants without the need of stopping the work of production, or, if the finished boarding should so accumulate as to be a hindrance to the effective operation of the machine, the completed product could be removed by assistants without stopping the machine. Time for removing the finished boarding need, consequently, be provided but once for each machine set-up, but the selected time, established by time study, should be increased by the customary "variation allowance" of 25 per cent.

The machine time, or to be more exact, the time required for feeding the boards to the machine, matching and ripping the finished boarding to required width, is dependent upon the speed of the machine carriers. The chains of these carriers are of the long link variety and the carrier dogs are attached at regular intervals, with the requisite number of chain links intervening to accommodate the boards of different assorted lengths. The conveying capacity of the machine carriers, the chain speed having been standardized and calibrated, is, then, dependent upon the space between successive carrier dogs, rather than upon the length of the boards handled. For instance, if the chain links are 8 inches long, the carrier dogs attached to every sixth link, and the chain speed 72 feet per minute, the capacity of the machine—providing for a variation

allowance of 5 per cent. in chain speed — expressed in the capacity number of boards handled, would be 17.14 per minute $\left(\frac{72 \times 12}{6 \times 8 \times 1.05}\right)$, or 1,028.4 per hour. Such rate would necessitate a board between each pair of carrier dogs, a perfection of operation not attainable in practice, and makes no provision for a pro-rated time allowance for the necessary preparation of the machines, the set-up or for moving the trucks, so measures an ideal production during continuous machine operation. Should the necessary time allowances, based on one set-up per day of ten hours (600 minutes) be, for the "necessary delays," 56 minutes; the machine set-up, 5 minutes; moving supply truck of rough boards, 5 minutes; and removing truck of finished boarding, 4 minutes—a total of 70 minutes—the possible operating time of the machine would be reduced to 53 minutes per hour and the ideal capacity to slightly over 900 boards in the hour (17.14 × 53). Any such production is unattainable under ordinary working conditions, but by production studies a task production, upon which rate of recompense may be based, can be accurately and equitably established. It is obvious, however, that the most that can be expected is to keep as uniform a flow of rough boards passing on the carrier as is possible and, in productive operation, the attainable production is considerably less than the ideal. This "attainable production" may serve as a basis for estimates of production and of costs, but it is not considered in figuring the earnings of the workers, once their rates have been established. It is of interest, nevertheless, in that it is an influencing factor in the establishment of equitable piece rates.

A counter on the dovetailing machine records the actual number of rough boards utilized, and the earnings of the operators, the leader and the helpers, are based entirely upon such recorded number of boards passing through the machine. Their earnings are computed by the simple formula,

$$E = NR + \frac{CR'}{100}$$

Where,

E = Total earnings.
N = Number of set-ups.
R = Rate per set-up.
C = Number of rough boards utilized from counter.
R' = Rate per 100 rough boards.

The rates per set-up and per hundred rough boards differ, as a rule, for the leader and for his helpers, but the same formula is applicable to the computations of their respective earnings.

A typical illustration would be in figuring the earnings for passing 7,200 rough boards on five different machine set-ups, the leader receiving \$0.03 per set-up and \$0.05 per 100 boards, while the helpers' rates were \$0.025 and \$0.045 for the set-up and 100 boards, respectively. The leader would receive \$3.75 for the work and the helpers \$3.37 each—see example—placing the labor charge per hundred boards at \$0.1925.

Example:

$$N = 5, \quad C = 7\,200, \quad R = \begin{matrix}\$0.03 \text{ for leader,} \\ 0.025 \text{ for helpers,}\end{matrix} \quad R' = \begin{matrix}\$0.05 \text{ for 1 leader,} \\ 0.045 \text{ for helpers.}\end{matrix}$$

$$E = 5 \times 0.03 + \frac{72 \times 0.05}{100} = \$3.75 \text{ for leader,}$$

$$E = 5 \times 0.025 + \frac{72 \times 0.045}{100} = \$3.37 \text{ for helpers.}$$

$$\text{Labor charge per 100 boards} = \frac{3.75 \times 3 \times 3.37}{72} = \$0.1925$$

In the foregoing example, the various rates are taken as average mean rates for the various set-ups, in order to simplify computations. Any averaging of such character would not be resorted to in actual practice, however, for the rates differ for each set-up of boards of certain assorted lengths, and, if five set-ups were required, several assorted lengths of boards would have to be handled, for each of which the rates would differ.

It will have been noted throughout the explanation of the method of rating that no mention has been made of the width of the rough boards employed or of the width of the finished boarding, and that all computations are based simply on the lengths of boards suitable for the various set-ups. Naturally, the width of finished boards required will differ, though the width of the rough narrow boards should be practically constant, and if the required width of finished boarding is in excess of that attainable from two rough boards additional work will be entailed for the finished product. The wider boards are obtained by passing made-up boarding, not sawed to width, as make-up boards to be joined to rough boards from the supply end of the machine. Unsawed made-up boarding of any number of rough boards which with one or more rough boards will produce a made-up board of sufficient width to allow sawing to specified dimensions may be employed in this manner. That is, the make-up boards may be of one, two or any number of rough boards, dovetailed and glued together, required for the width of the finished board.

Output of finished boarding will vary, then, with the number of narrow boards employed for its production, so the one rate of recompense for the various set-ups covers the make-up of boarding of any width within the capacity of the machine. The output of wide boards may not be exactly inversely proportional to the number of rough boards required for their make-up, but is approximately so and may be so considered for planning and estimating purposes.

APPENDIX XII

WAGE PAYMENT SYSTEMS

APPENDIX XII

WAGE PAYMENT SYSTEMS

THE purpose of taking time studies is to secure information for the setting of rates, which in themselves are one of the elements of wage payment systems. Several forms of such systems have been and are being used in establishments where time-study work has been done and, in fact, in some cases a variety of wage systems has been installed in the same plant in order to meet varying conditions.

In general, these wage systems may be divided into four main groups: day-work, piece-work, task and bonus, and premium. So this appendix will take up these four groups with particular reference to the piece-work, task and bonus, and premium plans. The purpose is to sketch briefly the differences and distinctions between these various systems, in any of which the times established by time study can be used as a basis for fixing the rates.

Those who have followed closely the developments in the handling of labor during the past few years will have suggested to their minds various methods of profit-sharing; it is not the purpose to treat of any of these, but to restrict the discussion to accepted methods of wage payment.

The commonest, most widely used and probably the most ordinary method of paying wages in industry is the day-work plan whereby the employees are paid so much per hour or so much per day, the amount being arbitrarily fixed and governed to a great extent by local conditions. It is at once recognized that this plan is not based on definite facts, and unless administered with unusual care will result in improperly rewarding the work and efforts of some of the operators compared with others.

Ordinary piece-work is the next in point of widespread use. While it is very true that this form of piece-work does decrease supervision—in this particular it is a help in industry—another of its efforts is the lessening of responsibility on the part of the executives, and in this respect it is a step backward in industrial management. With the usual methods of setting piece-work rates there is no attempt at planning, routing or doing the

necessary preparatory work in order that the workman will be enabled to turn out an amount of work satisfactory to himself and to the management, for the rates are usually based on past performances or some kind of a guess made by the foreman. All of these methods are opposed to the modern trends in industry, and are thus antagonistic to the methods that have been put into effect in connection with time-study work.

As the developing of the piece-work system was an attempt to improve upon day-work, likewise the Taylor differential piece-work, task and bonus and premium plans were evolved to improve upon the ordinary piece-work system. Each of these is described in the latter part of this appendix and a comparative chart shows their relationships.

Time study is not only the sound basis for setting times for the accomplishment of a task, but should be the basis for setting the recompense as well. In piece-work systems, this relationship holds true, and it should be equally true in all just bonus and premium plans of recompense for work accomplishment. Furthermore, as recompense should be commensurate with the service rendered, and the time element should be a governing factor in both rate and recompense setting, wage payment systems are intimately associated with all proper time study for rate setting.

In an address before the National Metal Trades Association in New York, April 4, 1910, Carl G. Barth reiterated forcibly the need for equitable and just rates of recompense for the worker for the accomplishment of a substantial task, and for the necessity of the assumption by the management of full responsibility for all conditions affecting the comfort and convenience of the worker. Mr. Barth's remarks bear repeating:

> "No particular mode of paying workmen can alone remove the distrust and misunderstanding between employers and employees. What is needed is co-operation between them. As often as they together accomplish a substantial task, the workman should be given, in addition to his regular wages, a fair share of the extra profits. Further co-operation means that the employer examines into everything that must be attended to before the employee can actually devote himself to the job for which he is especially fitted and hired. Perhaps he is wasting time getting material, drawings or tools, or there is something the matter with his machine, or the work is not that for which it is best fitted. Even a first-class mechanic may not know enough about the art of cutting metals to select the most economical feed and speed for his work.
>
> There is no end to the things that are part of the business of a manager to look after carefully and systematically, to get the most out of machines and their attendants, and make the latter feel that their comfort and ease of mind are considered."

The simplest of all wage-payment systems is, of course, the day-work plan, in which the workers are divided into certain classes and a definite rate of wage paid to each class. As practiced in the industries, the classification is, perforce, general in the extreme, and the worker is not paid according to individual worth, skill, and reliability.

Differing radically from the day-work plan is the ordinary flat piece-work system. Under this, labor is paid a fixed rate for all work actually performed, and it would be the ideal system of wage payment were the rates commensurate with the work and equitably set for all conditions. Piece-work is far from being a development of modern times and was probably a fairer and more just basis of labor recompense in the earlier days than under the complex industrial activities of more recent years. In the old days, rates of recompense were set by foremen who had themselves performed the rated tasks on the same machines and in the same manner as required of the workers. Rates were set by men who knew from personal experience the difficulties of the task, who trained and assisted their workers, and who knew the limitations of both men and machines.

As industrial establishments became more complex, as new machinery was introduced with which the foremen could not be so familiar from personal experience, and the intimate personal contact between workers and instructors was lost, rates were guessed at or arrived at from insufficient, and not infrequently erroneous data, with the result that piece-work rates in many instances were neither just nor equitable. Other factors also adversely influenced the situation.

In the first place, if labor is to be valued in direct proportion to its productiveness, as under any piece-work system of recompense, every act or condition in any way tending to reduce or delay production must be eliminated as far as possible. The best equipment must be furnished the worker, supplies must be on hand when required, and no factors should be introduced that will interfere with his productive activity. That is, all delays of any kind must be eliminated, or, at least their occurrence reduced to a minimum, and the worker must not be called upon to perform any act that will consume time during which he might otherwise be profitably employed at his specific task. In other words, if the worker is to be paid for only the work he does, he should be provided with work to do every minute he is at the employer's plant. The employer has no right to the worker's time when he is not productively employed through managerial failure to provide work and facilities for performing

it, except he makes a suitable recompense for the loss sustained. The management must assume its full responsibilities if the basic justice of piece-work recompense is to be realized.

Even in a plant where the management does assume its proper responsibilities of providing adequate equipment and maintaining it in effective operating condition, planning the work and its procedure, instructing the workmen in methods and approved ways of doing the work, providing all comforts and conveniences that the nature of the work will allow, and in general relieving the workmen of all responsibility for acts other than those for which he was engaged—even in such a plant it cannot be denied that delays to the smooth progress of the work over which the workmen have little or no control are liable to occur. It is the function of proper time study to eliminate such delays so far as possible and to make due allowances for such as cannot be entirely eliminated.

Both the day-work plan of wage payment and the straight piece-work system based on past performances are thus open to objections. Yet around these simple basic methods of recompense all wage systems are built up, for either the worker is paid for his time, for the amount of work he does or for realizing a set base time.

The injustices and inequity of the simple systems have been eliminated to a considerable extent in some of the more advanced wage-payment systems and with marked progress toward attaining the principal objectives of both employer and employee—in the case of the employer, *low production costs*—for the worker, *high wages*.

Quite obviously the first necessity in arriving at equitable rates of payment, whether they be for day-work or piece-work, is a true measure of the work to be performed, and for such a measure to be accurate, time study is an essential factor. Only by time study,[1] meaning time study in its broadest and most comprehensive sense, can the facts be established which guard against the cupidity alike of employer and employee in arriving at an equitable valuation of a definite task. Time study, properly conducted, establishes not only the net time any piece of work should take under ideal conditions, but, by adding the allowances[2] established through years of trial and error application, sets a task time in which any one qualified for the work should be able to perform it repeatedly and regularly, by following the definite directions given on the instruction cards

[1] See Chapter I.
[2] See Chapter V.

that form an essential element in the practical application of time study to rate setting.

A definite task rate which the average worker can equal repeatedly without undue fatigue or discomfort is only arrived at by time study, this being the "minimum selected time" plus necessary allowances.

With these all important considerations known—not guessed at or estimated, but accurately established—it is a comparatively simple matter to place an equitable labor valuation on the work to be done and adopt a system of wage payment suited to the conditions.

The rate set by proper time study, based on the time allowed for the completion of the task, is, however, considerably greater than the productive rate that the average worker would be able to establish were he left to figure out by himself how to perform the work, what tools to select, what machine feeds and speeds to employ and what procedure to follow, for the rate is arrived at from an expert investigation of tools, methods, conditions and procedures, and the proper assistance that should be rendered to the operator. In short, the task time is set with the requirement that all managerial responsibilities must be fully discharged so that the acts that the worker is to perform are but those for which he is particularly suited and for which he is hired. The worker is not called upon to do anything which had not been considered as a factor in determining the task time, and for which he is entitled in every sense to be paid. Proper allowances are made for all necessary delays, fatigue, and the like, so that the employer is assured that conditions are favorable and equitable for steady and effective work on the part of the employee. As the output per employee should be (and in practice is) considerably higher with the aid afforded by time study work, and the worker must apply himself more assiduously to his task and so more effectively than when left to his own devices, time study makes possible substantial increases in the amount of wages earned by the worker. At the same time, lower production costs are made possible, so that differential rates, task work, and the payment of bonus or premium become advisable factors in the introduction of wage payment systems where time studies are to be used as a basis for determining equitable and just rates.

It is an established fact that to secure the continued interest and application of a worker to his task, and to impel him to expend his best efforts, some incentive is necessary. In general, incentives are of two kinds, the financial and non-financial.

The first is wages, and to bring out the active co-operation of the worker in striving to reach or better the task time the opportunity must be presented to earn more than the previous prevailing rate. The non-financial incentive may take the form of a hope of promotion, personal or departmental rivalry, an expression of the creative instinct—the desire to make—or some other human emotion. It must be confessed that this type of incentive has not been developed to a great extent in industry, so in the case of most workers the incentive to better and greater production is a wage increase, for by the money so received natural desires, both material and intellectual, can be satisfied. So practical considerations dictate that the incentive for industrial workers should take the form of bonus or premium based on the worker's regular rate of pay, whether this be computed by the day or by the piece. It is important that the incentive should be commensurate to the effort required for the accomplishment of the set task—neither too much nor too little. Dr. Frederick W. Taylor found that to secure maximum output quite clear-cut percentages, depending upon the character of the work, should be added to the regular rates of pay. He recommended wage increases as follows:

> "For ordinary shop work, such as the ordinary kinds of routine machine operations, requiring no particular mental concentration, close application, skill or hard work, a premium or bonus of 30 per cent. of the regular wages; for ordinary day labor requiring no special mental effort or skill, but calling for strength and bodily exertion producing fatigue, from 50 to 60 per cent.; for work requiring skill or considerable mental application coupled with close application, but without severe bodily exertion, from 70 to 80 per cent.; and for work entailing skill, mental concentration, close application, strength and severe bodily exertion, an increase in average wage of from 80 to 100 per cent. is necessary to secure maximum production."

Such increases in pay have been found to be productive of highly beneficial results to the workers affected. Men tend to become more thrifty when they receive such proper recompense for their effective day's work, live rather better, save money, and work more steadily. In short, they more fully realize the value of money. On the other hand, larger percentages, resulting in unduly high wages, have repeatedly demonstrated a tendency to make many workers irregular in their attendance and, frequently, more or less shiftless, extravagant and, sometimes, dissipated; while lower percentages do not prove sufficient incentive for workers—that is, a large proportion of our industrial workers—to do their best over any continued period.

Doctor Taylor also evolved a system of wage payment in

which incentives in the form of increased rates for the accomplishment of measured tasks formed the basis for a comprehensive "differential" piece-rate system of recompense. In fact, the Taylor differential piece-rate system was the first plan to ignore all records of past experience in the matter of rates of production, or the length of time a task should take, and to base task time upon time-study deductions, adding specific instructions as to how the task should be performed as an aid to the workman. Approved time-study practice by qualified observers, detailed instructions to the workman and the effective co-operation between the time-study department and the workmen, are essential for the successful introduction of the Taylor system of differential wage payment.

A definite task or rate of work is established by time-study observations in the Taylor differential piece-rate system, which can be steadily performed, without undue fatigue or discomfort, by the diligent worker who follows the detailed instructions furnished on the instruction card for the task. As the accomplishment of the task within the time allowed calls for interest and application on the part of the worker, a substantial premium is paid if the task is completed in the time allowed. This bonus establishes what is termed the "high rate," and in machine-shop work is customarily taken as 33⅓ per cent. of the worker's base rate. So the worker equalling or bettering the task time is paid at a rate of one and one-third times his regular rate of pay for all such effective production. The "low rate," which is five-sixths of the "high rate" of pay, or 83⅓ per cent. of the rate which the worker would receive for straight piece-work, is imposed only when the worker, through lack of application to his work, fails to equal the productive rate accurately set by time-study investigations, a rate which is proportioned so as to be within the ability of the average worker to equal repeatedly without undue fatigue or discomfort.

Under the Taylor system a very substantial premium is paid for the accomplishment of a task within a time limit, making all reasonable allowances for delays, etc., and for which explicit instructions are furnished, by which the worker of average ability can earn the premium repeatedly and steadily. The penalty of "low rate" is imposed only for lack of application or failure through ignoring instructions.

Henry L. Gantt devised a plan of recompense not dissimilar to the Taylor system in that a substantial premium or bonus is paid for task accomplishment, but different in that no "low rate" or penalty is imposed for failure to equal the set produc-

tion rate. As originally introduced, the Gantt system consisted in determining a task time by time study, and allowing a proportion of such time as a bonus if the rate thus established was equalled or bettered. Failure to make the set rate involved no penalty, however, and the worker received his regular rate of recompense, but without the bonus. Later, Mr. Gantt modified his system by adding a fixed amount of recompense to the regular rate for the task whenever the work was completed in, or better than, task time, but, as under his original plan, no penalty was imposed should the worker fail to accomplish his task in the set time, other than the sacrifice of the bonus.

Though Doctor Taylor was the first to make use of a scientific system of recompense in connection with work under his direction, it was F. A. Halsey who first presented to industry in general a wage payment system intended to reward a worker for unusual application to his work, otherwise than by straight piece-work. Under the Halsey plan of recompense it is entirely optional with the workman whether he elects to work on the premium plan or not, for his regular rate of pay is assured in any event. The plan consists in setting a fixed time in which to complete a specific piece of work, and for each hour the workman may shorten this time in the performance of the work, he is paid a proportion of his hourly wage as a premium. That is, if the incentive is set at $33\frac{1}{3}$ per cent.—the value selected by Mr. Halsey when he devised his plan—and the set time for the task is 10 hours, a worker who completed it in 8 hours would receive pay for eight hours at his regular rate, and additional pay for one-third of each hour saved in the discharge of the work—that is, he would receive pay for $8\frac{2}{3}$ hours for the 8 hours of actual work. Should the same rate of accomplishment be continued throughout a day of 10 hours, the recompense received by the worker for the day's work would be equivalent to the pay for $10\frac{5}{6}$ hours at the regular rate. Or if the premium basis had been set at 50 per cent. the application of the worker would have earned for him 9 hours pay for the 8 hours and a recompense of $11\frac{1}{4}$ hours for the day of 10 hours.

At the time the Halsey premium plan was first introduced, Mr. Halsey was not aware that time study had been used as a basis for the rate setting, so his set time for the task was arrived at from records of past accomplishment or previous experience. However, the Halsey plan adapts itself to the refinements of time-study deductions, but when setting a premium time from a time study it is always desirable that when the task time is equalled the excess earnings be a predetermined amount. If

the proper incentive is set at 33⅓ per cent. of the regular rate of pay, and the worker is to receive full pay for half of all the time he may save in completing his task—*i. e.*, full pay for half the difference between the set task time and the time actually taken to complete the task—it becomes necessary to increase the task time by 66⅔ per cent. to arrive at a basis for figuring the premium earned for task accomplishment in task time. For example, if the task time determined by time study be nine hours, 66⅔ per cent., or six hours, is added, making the time basis 15 hours. Then, if the task should be completed in 9 hours—the task time—the time saved would be computed as 6 hours and the worker would receive straight pay for 9 hours and a premium or bonus equivalent to full pay for 3 hours, making his total recompense equal to straight wages for 12 hours work. That is, for having accomplished the task in the time set—9 hours—he would earn the proper incentive based on 33⅓ per cent. of the regular rate of pay.

Under the Halsey plan, the workman is assured of his regular day wage, even if he should not succeed in completing his work within the time set, and may make a substantial premium in addition by making the set rate. It is a simple method of recompensing workmen for all unusual accomplishment and is generally considered as fair by the workers as well as by the employer.

Another premium plan, one that has met with considerable favor in Great Britain, was introduced by James Rowan, of Glasgow, Scotland. Under the Rowan plan, which is in reality a modification of the Halsey plan, a task time is set and for betterment of this time the regular day rate of the worker is increased by a percentage computed as the ratio of the time saved to the time allowed for the task. The relationship of this plan with others is shown on the diagram of Fig. 135 of this appendix.

With the idea of improving on the Halsey and Rowan premium plans, Carl G. Barth developed a premium system for which there is a simple and convenient mathematical expression. Under this system the total earnings in hours equal the square root of the product obtained by multiplying together the total time allowance and the total time taken. This plan has the advantage that it is readily interpreted by means of a very simple slide rule.

The full significance of Mr. Barth's premium plan, as compared to the Halsey and Rowan plans, is clearly shown in Fig. 135. In his address before the New York Metal Trades Association in New York, April 4, 1910, from which a quota-

tion appears on page 334, there was presented a diagram comparing the several wage-payment systems that have become more or less prominent. This diagram is reproduced as Fig. 135.

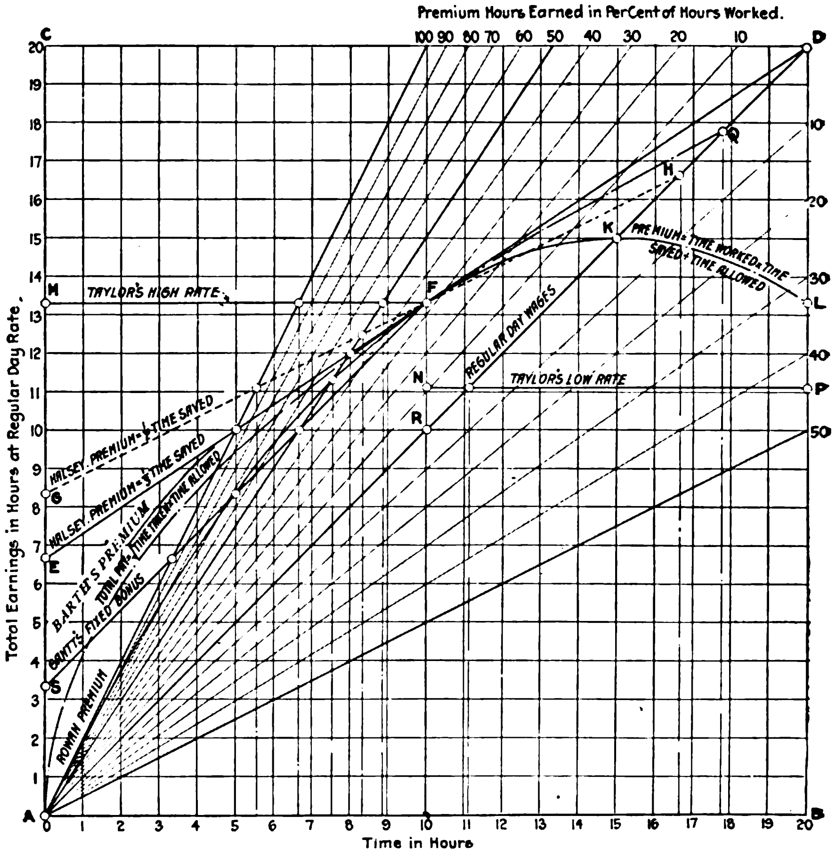

FIG. 135.—GRAPHIC DEPICTION OF WAGE PAYMENT SYSTEMS

No better comparison of the five systems under discussion can be given than this one that brings out their features in graphic form.

Herewith are the various mathematical expressions covering the premium plans just described.

Halsey plans:

$Tp = \dfrac{T + t}{2}$, where one-half of the time saved is allowed.

$Tp = \dfrac{T + t}{3}$, where one-third of the time saved is allowed.

Rowan plan:

$$T_p = t\left(2 - \frac{t}{T}\right)$$

Barth plan:

$$T_p = \sqrt{T \times t}$$

Where:

T_p = total earnings in hours at regular day rate.
T = total time allowed by time study.
t = total time taken by operator.

The curves of Fig. 135, depicting the various plans, are based on the assumption that the task time in every case is 10 hours and that the rate of pay, when production equals the task rate, is the same as the Taylor differential high rate. These are: For the Halsey premium plan (one-third of the time saved) curve *E-F-D;* Halsey premium plan (half of the time saved) curve *G-F-H;* Taylor high rate; curve *M-F;* Taylor low rate, when the task is not equalled, curve *N-P;* Gantt's original fixed bonus, curve *S-F-R-D;* Gantt's modified bonus *M-F-R-D;* Rowan premium, curve *A-F-K-L;* and Barth premium, *A-F-Q.* The diagonal line *A-R-D* indicates earnings at regular day wages. The Taylor differential piece-rate system and the Gantt modified task and bonus plan offer a greater incentive for obtaining high production than any of the other schemes. But the Gantt plan and all the others except the Taylor differential guarantee the workman his regular rate of pay even though he does not succeed in performing his work in task time.

A requisite for the setting of rates under a piece-work plan is the classification of various kinds of work according to the experience necessary for its performance, the skill or physical exertion required, the hazard or discomfort of the work, working conditions and other modifying factors. This classification takes the form of an hourly rate valuation, and corresponds to the hourly day rating. It is known as the base rate and appears as one of the factors necessary in establishing and operating a piece-work system. The management exercises the same control of these base rates that it does of day rates. The time study department determines the task times and with the base rates, fixes the rate per unit. This process is parallel with the setting of the day rates which are necessary in day rate, premium and bonus plans. But it must be clearly understood that these base rates apply only to piece-work plans.

An example of piece-rate classification follows:

Class	Operation	Base Rate per Hour	Task Earnings per Hour Should Be
Drilling small parts.			
A	Drilling, countersinking, counter-boring, gage and sensitive drilling.	$0.33	$0.44
B	Drilling clearance holes where working holes are drilled before machining and centering	0.30	0.40
C	Boring and counterskinking.	0.27	0.36
D	Boys' work	0.21	0.28
Drop forging.			
A	Heavy parts (weighing approximately 15 pounds each) where skill is required to hold the part to size.	0.48	0.80
B	Light parts (weighing approximately 8 pounds each) where skill is required to hold parts to size.	0.42	0.70
C	Heavy parts (weighing approximately 15 pounds each) where there is no necessity for close sizing.	0.39	0.65
D	Light parts (weighing approximately 8 pounds each) where there is no necessity for close sizing.	0.36	0.60
Power milling.			
A	Split milling, octagon milling, and splining milling, where reliance is placed on the operator's skill to produce good work	0.30	0.40
B	Work where the piece is located by mechanical means, as pins, set-blocks, and the like	0.27	0.36
Hand Milling.			
A	Work where there are delicate cuts, or cuts requiring gaging.	0.30	0.40
B	Clearance cuts only	0.24	0.32
C	Boys' work	0.18	0.24
Press work.			
A	Work where the operator sets up his own dies	0.27	0.36
B	Work where the dies are set for the operator	0.24	0.32
Splining.			
A	Work where reliance is placed upon the operator's skill to obtain proper gage fits	0.30	0.40
B	Work that is located by mechanical means, such as pins, set blocks, and the like	0.27	0.36

It will be noticed in the preceding tabulation that the inducement on the drilling, milling, splining, and presswork operations is 33⅓ per cent., while on the forging operations, where skill, physical strength and discomfort from heat and gases must be endured, the inducement is set at 66⅔ per cent.

Let us turn now to the direct bearing that several plans of wage payment have in connection with time study in its application to task and rate setting. Those that need to be considered are day work, straight piece-work, the Taylor differential piece-work, Gantt modified task and bonus and the Halsey premium plans. To illustrate the application of these in a clear manner let us take as our example the drilling of a machine part the task time for which has been determined by time study to be 3 minutes.

Day-work plan:
Task time, per piece, 3 minutes.
Task production, per hour, 20 pieces.

Close supervision and personal interest on the part of the worker would be necessary to maintain this production, as under the day-work plan the preparation work is not, in general, looked after by the management and the workman is left to his own initiative in determining the methods to be followed.

Straight piece-work plan:
Task time, per piece, 3 minutes.
Task production, per hour, 20 pieces.

If we assume that the work belongs in Class *A* drilling, as defined above with a 33⅓ per cent. inducement, the piece rate would be $0.33 per hour, and the price per piece would be:

$$\frac{3}{60} \times 0.33 \times 1.33 = \$0.0222.$$

The three factors in this multiplication are, first, the number of hours required per piece (3 minutes divided by 60 minutes), second, the base rate per hour and, third, the unit payment plus the inducement factor, or 1.33.

Taylor differential piece-work plan:
Task time, per piece, 3 minutes.
Task production, per hour, 20 pieces.

Let us assume that the base rate and the inducement are the same as in the straight piece-work plan above. Then for the Taylor higher rate the price per piece would be:

$$\frac{3}{60} \times 0.33 \times 1.33 = \$0.0222.$$

This applies when the task time is equalled or better.

For the Taylor low rate the price per piece would be:

$$\frac{3}{60} \times 0.33 \times 1.33 \times 5/6 = \$0.0185.$$

This applies when the time taken is longer than the task time

of 3 minutes, and involves the penalty represented by the factor 5/6, or a lower rate per piece.

Gantt modified bonus plan:
Task time, per piece, 3 minutes.
Task production, per hour, 20 pieces.

Let us assume that the hourly rate of the worker is the same as the base rate and the inducement is the same as used in the preceding examples.

Then, if the task time of 3 minutes is equalled or bettered, the worker is allowed 4 minutes pay for each piece; that is, an increase of 33⅓ per cent. If, however, the time taken is longer than the task time the worker is paid at the day rate only.

Halsey premium plan:
Task time, per piece, 3 minutes.
Task production, per hour, 20 pieces.

Let us assume that the day rate is the same as the base rate in the preceding examples, and that the inducement is likewise 33⅓ per cent. To the task time of 3 minutes is added 66⅔ per cent., giving a total of 5 minutes, which is called the time basis.

This method gives the worker a premium consisting of one half of the time saved for every piece that is performed in a shorter period of time than the time basis, which in this example is 5 minutes. This premium time is added to the actual time taken. When the task time is just equalled the worker's earnings under this plan are the same as in the previously described plans, for the increase is one half of the addition of 66⅔ per cent., or 33⅓ per cent.

It will be noted in all these examples that when the task time is just equalled the earnings are identical.

During times of unusual labor conditions when wages are rising rapidly, as during the years 1917–18, it is necessary to make use of some expedient for increasing the earnings of workers, but without disturbing either the base rates or the percentages of inducement. To meet this situation the author developed a system of wage payment by means of which differential bonuses are applied to time-studied piece-work rates. This method of raising wages is particularly efficacious, for, by offering an unusual opportunity for earning a high rate of pay for close attention to the task the dropping of production which usually follows any sudden rise in wages—especially if the sudden increase has been substantial—may be arrested, in fact production may be increased. This plan was introduced

in one of the large plants of the country making munitions in those departments where the work had been time studied. The differential bonus was 20 per cent. for task attainment, and 10 per cent. for an accomplishment between five-sixths of the set task and the task itself. That is, the worker accomplishing the measured task within the time allowance earns a bonus of 20 per cent. added to his regular piece-work earnings, while the worker accomplishing from five-sixths up to the full task in the time allowed for the task receives a bonus of 10 per cent. of his regular piece-work earnings. Failure to accomplish at least five-sixths of the task in task time penalizes the worker in that he receives but the regular piece-work rate for his accomplishment. These specific differential bonuses applied to straight or flat piece-work rates are graphically shown in Fig. 136.

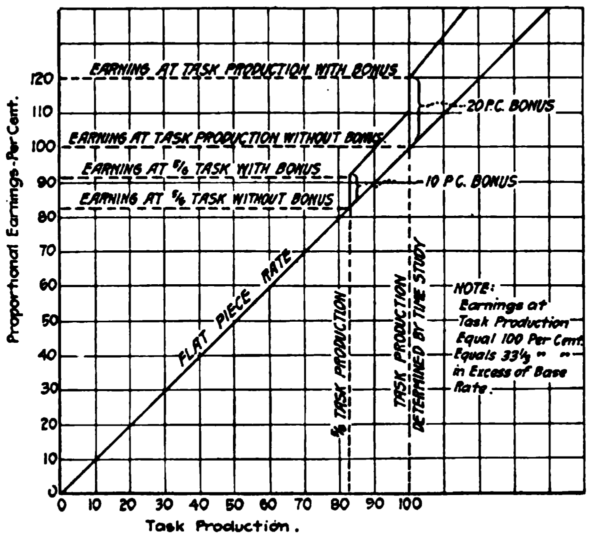

FIG. 136.—DIFFERENTIAL BONUS APPLIED TO FLAT PIECE-WORK

The appeal of the differential bonus is marked in this system, as is forcibly demonstrated by the graphs depicting the result of introducing the differential bonus in a department employing about 150 girls on an operation conducted on a piece-work basis. The curves indicate the number of girls who worked the full time of 10 hours per day before and after the introduction of the bonuses, and their proportional accomplishments per 10-hour day in per cent. Curves *b* and *a* show the number of girls working full time and their earnings per 10-hour day, as indicated by their respective percentages of task accomplish-

ment, for the week immediately before the introduction of the bonuses and for the preceding week, respectively. Graphs *c* and *d* show the records for the week following the introduction of the inducements and for the succeeding week. Not only did the appeal of the bonus cause many more girls to work regularly, but a very much larger proportion of the steady workers attained a production of 100 per cent. (the accomplishment of the work in task time) or better. A bonus of 20 per cent. of their piece-work pay was earned. About twice as many girls were able to reach an accomplishment of 83⅓ per cent. (five-sixths of the set task rate) when an inducement of 10 per cent. over regular piece-work rates was offered. Even in the case of the laggards, whose accomplishments were below rates of 70 or 75 per cent., the number with such poor records was materially reduced just as soon as the bonuses were introduced. In short, the appeal of the differential form of bonus applied to a flat piece-work system materially increased the productiveness of the workers.

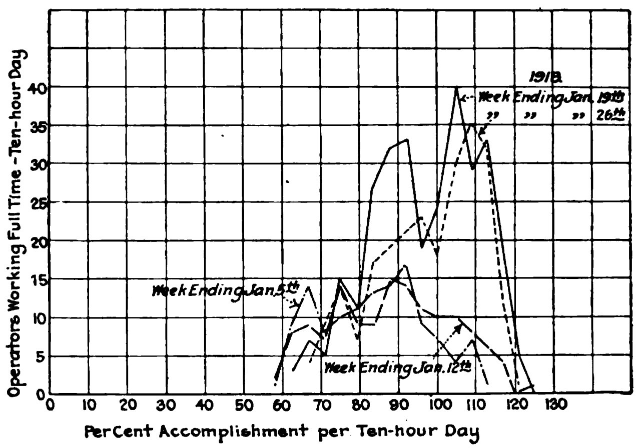

FIG. 137.—EFFECT OF DIFFERENTIAL BONUS ON PRODUCTION

The success of these various systems of promoting production by the expedient and equitable procedure of paying the worker a share of the gains realized from his more effective application to his work is, quite naturally, further assured if the worker has the interested co-operation of such indirect producers as the adjusters, tool setters, instructors and overseers. These workers have it in their power to be of considerable assistance to the actual producers, the workers, by constructive advice, helpful criticism, and the smoothing out of the minor delays

and inconveniences that never can be entirely eliminated. In establishments where parts are made in quantities, these supervisors usually look after from 10 to 30 machines or operators, naturally their responsibilities are more or less divided and there is little likelihood of their duties becoming purely routine in nature. For these reasons it is neither advisable nor fair to put them on a piece-work rate basis of payment, dependent upon the production of the group they supervise, for it is just as probable that the group contains some inexperienced operators as that it includes some highly experienced ones—a condition over which the supervisors cannot be expected to exercise more than nominal control. The supervisor can and should raise the group production, but should not be expected to raise the standard of the least experienced workers to the mean group productiveness, nor to keep the group output up to the rate set by the most skillful operator.

The group supervisors are recruited from the ranks of the operators and are rightfully entitled to a somewhat higher rate of pay than that of the class from which they have been promoted, else there would be no incentive for an operator to strive to become supervisor. If the operators are on piece work, as they frequently are, and the supervisors should be dependent upon group productiveness for their rate of recompense, it would be quite possible for the more skilled operators to earn more than the supervisors, as the supervisor's rate should not be much greater than that of the operators. Paying the worker more than his supervisor would be detrimental to the effective development of the plant organization, for the more skillful operators would have no tangible incentive to qualify for positions of supervision. On the other hand, if the supervisors are paid at day rates, equitably proportioned to the earning capacity of the group, while the operators work on piece rates, there is no particular incentive for the supervisors to strive to maintain high group production.

To meet this situation a piece-work bonus plan in addition to a day-work guarantee has been evolved as an incentive for the supervisor to strive for group productiveness where the operators are working on piece rates. The supervisor is paid a regular hourly wage and in addition a proportional bonus for each machine in his charge that attains a bonus-earning production.

To show more specifically the method used in applying and computing the bonus for machine adjusters or supervisors the following example is worked out:

Let the base rate per hour for the machine adjuster equal a, and let the number of machines over which he has charge equal n. Then he has a base rate per machine equal to $\frac{a}{n}$. Whenever one of his machine operators produces the task number of pieces per hour, N, the adjuster is paid ⅓ of his individual base rate, $\frac{a}{n}$, or a rate of $\frac{a}{3n}$ per machine, or $\frac{a}{3nN}$ per piece. This bonus will become proportionally greater for the performance of an operator who turns out more than N pieces per hour.

If, however, the operator turns out less than N pieces per hour a bonus of 5/6 of the above piece-work bonus of $\frac{a}{3nN}$, or $\frac{5a}{18nN}$, is to be paid to the adjuster down to the lower limit of $5/6N$ pieces. Below this limit no bonus is paid.

Let us assume that the task number of pieces for a machine is 4,540 per hour, and that the adjuster's base rate is $0.36 per hour when he attends to four machines. Then his bonus per hour will be as follows under three assumed conditions of output:

1. When 5,000 pieces are produced per hour.
2. When 4,000 pieces are produced per hour.
3. When 3,600 pieces are produced per hour.

(Note that the last two rates of production are smaller than the set task.)

The bonus rates are as follows for the three conditions:

1. $\frac{a}{3nN} = \frac{0.36}{3 \times 4 \times 4{,}540} = \frac{0.03}{4{,}540}$

   Hence the total bonus per hour $= \frac{0.03 \times 5{,}000}{4{,}540} = 0.033$ cents

2. The total bonus per hour $= \frac{0.03 \times 5 \times 4{,}000}{6 \times 4{,}540} = 0.0219$ cents

3. As 5/6 of 4,540 = 3,780, and as a production of 3,600 is lower than this lower limit, no bonus is to be paid in this case.

The foregoing method of paying a bonus to machine supervisors is more adaptable to those cases where the product runs the same from day to day. Where either operators or product change, a modified plan will be found easier to handle from a payroll point of view.

This modified plan is to multiply the number of machines by the number of working hours in the standard day, and arbitrarily to set a certain proportion of the machine-hour

product—usually 60 per cent.—as marking task attainment for the group of machines. By equalling or exceeding this task a bonus is earned, and for failure to maintain such a number of productive hours for the group the adjuster is penalized by loss of bonus. Under this plan, it is to the adjuster's interest to keep his machines productively occupied and the operatives under his supervision on a piece-work basis. On the other hand, it is to the worker's interest, just as soon as he fails to make more money on piece work than he could on day work, on account of failure on the part of the adjuster to keep his machine in effective operating condition, or because of any delay for which the adjuster may be responsible, to be asked to be transferred to day work. Such a transfer represents to the adjuster a net loss of so many possible machine-hours, and consequently makes it much more difficult for him to earn a bonus. Even should he be able to keep all the remaining machines productively occupied without interruptions and with enough operators on piece work for the piece-work machine hours to equal or exceed the required task attainment of the group, he loses a substantial share of his bonus by the loss of the machine-hour performance of the operator transferred to day work. However, so long as the adjuster succeeds in keeping the various machines in good operating condition, etc., their operators elect to work on a piece rate, as, by so doing they earn more than on day work.

To show this modified method of bonus payment in as clear a manner as possible the following paragraphs present an algebraic explanation and a worked-out example:

Let us assume that the base rate for a machine adjuster is a and that he is paid a bonus equal to ⅓ of this base rate, or $\frac{a}{3}$ per hour.

If h represents the standard number of shop hours worked per day, then the bonus per day is equal to $\frac{ah}{3}$.

As previously stated, 60 per cent. of the machine hours is taken as the number below which no bonus is to be paid. This is represented by $0.6\ n\ h$. The remainder, $0.4\ nh$, is the amount for which bonus is paid. So the bonus rate for excess hours would be $\frac{a\,h}{3} \times \frac{1}{0.4\,n\,h}$, which equals $\frac{a}{1.2\,n}$.

For convenience in figuring this production-hour bonus, and

to allow an opportunity to figure the earnings when the adjuster works only part time, the following method is shown:

Let t = total group hours.
k = bonus factor = 0.6 n.
w = hours worked by the adjuster.
e = bonus hours earned.
h = standard shop hours.
n = number of machines under the adjuster's charge.

The excess hours for which the adjuster is to be paid his bonus would be $t - kh$.

In order that the adjuster shall be paid only for his portion of the total number of hours the formula becomes: $\left(t - kh\right)\frac{w}{h}$.

That is, $\left(\frac{t}{h} - k\right) w = e$.

Example:

Let us assume that the adjuster is assigned to twelve machines and that his bonus rate is \$0.36 per hour. Then it is necessary to ascertain:

1. His bonus rate per hour.
2. His bonus factor k.
3. His bonus earnings for a day if the total active bonus hours were 85, the standard number of shop hours 8, and the number of hours worked by the adjuster 8.

To perform these calculations:

1. His bonus rate is $\frac{a}{1.2n} = \frac{\$0.36}{1.2 \times 12} = 0.025$.
2. His bonus factor is $0.6n = 0.6 \times 12 = 7$.
3. His bonus hours $= \left(\frac{t}{h} - k\right) w = \left(\frac{85}{8} - 7.2\right) 8 = 27.5$.

So his bonus earnings would be $27.5 \times 0.025 = \$0.69$. This sum is in excess of his regular day rate.

The two preceding plans, where an indirect producer works as an overseer, are not applicable, however, to indirect producers who are directing workers under the Halsey or any similar premium plan. Overseers or gang foremen who direct premium workers are naturally dissatisfied if the earnings of the more skillful and industrious men under their control exceed their own. As the industrious worker can frequently earn an average of 35 per cent. or even more of his standard day rate when working under the Halsey premium plan, to give the gang foreman a sum 20 per cent. greater, which is about the recognized difference in pay between workers and

their foremen, the day rate for the gang foreman would have to be about 55 per cent. higher than that of the worker. Such a high rate would be in excess of that usually paid to any one other than an exceptional foreman. So it is advisable to put into effect a bonus plan by means of which the gang foreman directing premium workers can earn more than the men under their charge, despite a day rate lower than the average earnings of their better men.

The author has installed a bonus plan of this character, by means of which the gang foremen are paid their bonus in the form of a percentage of their regular day's pay. This percentage is equal to the total time allowed the group in man hours in which to complete the task, minus the group premium time, actually employed on the tasks, divided by twice the number of total hours for the group, counting both day work and premium hours. The incentive of this plan is for the group foreman to keep as many of his workers as possible on premium time and earning as high premium as possible.

Following the method previously used, an algebraic explanation of this method of paying bonus and an illustrative example are given:

Let $T =$ the total time basis for the group.
Let t = the total elapsed premium time for the group.
Let G = the total elapsed hours worked by the men in the group, including both premium and day work.
Then $T - t$ = the time saved.

And $\frac{T - t}{2t}$ = the average bonus percentage earned by the group.

And $\frac{t}{G}$ = the percentage of premium hours worked by the group.

Let M = the percentage of bonus = $\frac{T - t}{2G}$.
Let L = total number of hours worked by the overseer during the bonus period, usually taken as one week.
Then $M \times L = N$ = the number of bonus hours for the overseer.
Let R = the overseer's day rate.
Then $N \times R$ = the amount of overseer's bonus.

Example:

To work out an illustrative example, let the total time basis for the group for the week be 1,190 hours; the total elapsed premium time for the week, 830 hours; the total elapsed time of all the men, including the day workers, 950 hours; and the total number of hours put in by the overseer for the week, 45 hours.

Then calculations must be made to supply the following figures:

1. What is the average percentage of bonus earned by the group?
2. What is the percentage of premium hours worked by the group?
3. What is the percentage of bonus to be paid to the overseer?
4. What is the number of bonus hours on which bonus is to be paid to the overseer?

1. $\frac{T - t}{2t} = \frac{1{,}190 - 830}{2 \times 830} = 21.7$ per cent.

2. $\frac{t}{G} = \frac{830}{950} = 87.5$ per cent.

3. $\frac{T - t}{2G} = \frac{1{,}190 - 830}{2 \times 950} = 19$ per cent.

4. $M \times L = 0.19 \times 45 = 8.5$ hours.

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